# Section 5
# Risk Characterization

Risk characterization integrates exposure data (e.g., PCB concentrations in surface water) and effects data (e.g., concentrations of PCBs in surface water that protect sensitive resident biota) to estimate risk. For this ERA, the integration of exposure and effects data includes but is not limited to the use of hazard quotients. The hazard quotient approach consists of dividing a single exposure point concentration (e.g., U95 PCB concentration) by a single, preferred toxicity reference value (TRV, e.g., chronic AWQC). The result is the hazard quotient or HQ.

$$HQ = \frac{\text{Exposure Point Concentration}}{\text{Toxicity Reference Value}}$$

HQs greater than 1.0 are indicative of risk, while those less than 1.0 indicate no significant risk. Numerically high HQs are not necessarily associated with more severe effects, but instead suggest *greater likelihood* of adverse effects actually occurring. Although such quotients are useful, limiting risk estimation to this simplistic approach fails to consider the variability and uncertainty in exposure and effects data. This ERA therefore supplements the hazard quotient method with other information to provide multiple lines of evidence to reduce uncertainty and increase confidence in risk estimation.

Contributing to the multiple lines of evidence approach used in this ERA are the following:

- comparisons of key exposure data (e.g., mean, U95, maximum PCB concentrations in exposure media) to one or more relevant effects concentrations or thresholds
- the results of the food chain model that estimates PCB dose via dietary exposure
- qualitative evaluations of observations and discussions of ecological significance
- HQs using carefully selected exposure and effects data.

Risks for ecological receptors are assessed on a media-specific basis. There is no appropriate method for combining risks from multiple exposure sources because the relative contribution to total risk from each source (e.g., surface water, sediment, soil, and biota) is unknown. For example, the relative contribution to overall risks to muskrats from surface water, sediment, soil, and food cannot be reliably determined. Also, the relative risk contribution from each source and for each species surely varies both spatially and temporally, especially as seasonal migratory and dietary habits change.

# 5.1 Risks from Chemical Stressors

The primary risks to ecological receptors at this site are from chemical stressors. A large variety of chemical contaminants have been detected in onsite media and in resident biota. However, this ERA is focused on assessing the risks from PCB exposures via direct contact with contaminated surface water, streambed sediment, floodplain (exposed) sediment, and surface soil, as well as ingestion of PCB-contaminated food items. Risks from drinking surface water and, except for food chain modeling for select species, from incidental ingestion of sediment and soil are not evaluated in this ERA because such risks are likely to be much lower than the risks from direct contact with exposure media and ingestion of contaminated prey. As stated previously, this ERA is focused on the most important stressors (PCBs) and exposure pathways for resident ecological receptors.

The following discussions of media-specific risks are based on presentations of ABSA-specific arithmetic mean, U95, and maximum exposure concentrations and relevant effects concentrations from multiple sources. For estimating risks, the most useful comparisons of exposure and effects concentrations are based on U95 exposure concentrations and site-specific effects concentrations or thresholds. These comparisons best represent reasonable upper-bound estimates of risk for site receptors. Although less useful, comparisons of more general effects concentrations to arithmetic mean and maximum exposure concentrations are included in the following discussions so that other levels of site contamination can be evaluated.

## 5.1.1 Risk from PCBs in Surface Water

Figure 5-1 presents mean, U95, and maximum total PCB concentrations in surface water for all sampled ABSAs and Portage Creek. Non-detect values are included in the mean and U95 values as either half the detection limit or a randomly assigned value between zero and the detection limit, depending on data source. Also included in Figure 5-1 are horizontal lines representing relevant effects concentrations, thresholds, or criteria for aquatic receptors. These concentrations are, from lowest to highest total PCB concentrations, the

- Michigan state water quality standard to protect wildlife (0.00012 µg/L)
- API/PC/KR-specific No Effect threshold to protect sensitive piscivorous consumers such as mink (0.0016 µg/L), based on 100% fish diet
- API/PC/KR-specific Low Effect threshold to protect sensitive piscivorous consumers such as mink (0.00197 µg/L), based on 100% fish diet
- EPA national chronic AWQC for PCBs (0.014 µg/L), to protect general piscivorous wildlife
- Lowest chronic value for aquatic plants (0.14 µg/L)

- Lowest chronic value for freshwater fish (0.2 µg/L).

These thresholds are taken from Table 4-9. The lowest three values listed are based on protection of wildlife rather than direct effects to aquatic biota. The EPA national chronic AWQC is based on protection of general piscivorous wildlife. The last two values are based on direct toxic effects to exposed aquatic biota. A comparison of these values supports the assumption that PCBs pose greater risks to wildlife, specifically piscivorous mammals and birds, and lower risks to aquatic biota.

Figure 5-1 reveals that all measured surface water total PCB concentrations exceed the Michigan water quality standard for the protection of wildlife and both the No Effect and Low Effect values for mink protection via dietary intake. Except for ABSAs 1 and 2, most surface water PCB concentrations exceed or approach the EPA national chronic criterion of 0.014-µg PCB/L surface water.

Only occasionally have measured surface water PCB concentrations exceeded or approached chronic effects thresholds for fish or aquatic plants. Direct toxic effects to invertebrates (lower range of chronic effects = 0.8 µg/L), or aquatic plants are therefore considered unlikely except at specific locations or times when PCB water column concentrations are likely to be highest (e.g., during storm events).

## 5.1.2 Risks from PCBs in Streambed Sediment

Figure 5-2 presents mean, U95, and maximum total PCB concentrations in streambed sediment for all sampled ABSAs and Portage Creek. Also included in Figure 5-2 are horizontal lines representing relevant thresholds or PRGs for selected representative receptors. These thresholds or PRGs are, from lowest to highest total PCB concentrations, the

- Sediment value (0.036 mg/kg) associated (based on site-specific sediment-water relationships) with the Michigan state surface water standard (0.00012 µg/L) to protect wildlife

- API/PC/KR-specific No Effect PRG derived to protect sensitive piscivorous consumers such as mink (0.5 mg/kg), based on 100% fish diet, site-specific mean BSAF, and calculated $EC_{10}$ (dietary no effect TRV)

- API/PC/KR-specific Low Effect PRG derived to protect sensitive piscivorous consumers such as mink (0.6 mg/kg), based on 100% fish diet, site-specific mean BSAF, and calculated $EC_{25}$ (dietary low effect TRV)

These sediment thresholds or PRGs are taken from Table 4-9.

Figure 5-2 clearly shows that mean, U95, and maximum total PCB concentrations in streambed sediments exceed all three thresholds or PRGs at ABSAs 2-9. At ABSAs 10 and 11, the maximum detected total PCB concentration in sediment exceeds or approximately equals all thresholds or PRGs.

PCB concentrations in API/PC/KR streambed sediments are likely to pose risks to sensitive benthic aquatic biota (e.g., macroinvertebrates) and water-column biota (e.g., invertebrates and fish) through release of PCBs from sediment particles. Also, sensitive piscivorous consumers such as mink are likely to be adversely affected by PCB-contaminated streambed sediments via the SED-IW-SW-fish pathway. The ingestion pathway is discussed in Section 5.1.4.

### 5.1.3 Risks from PCBs in Floodplain Sediment and Surface Soil

Figure 5-3 presents mean, U95, and maximum total PCB concentrations in floodplain sediment/soil for all sampled areas. Sample areas include floodplain sediments at the Plainwell former impoundment (ABSA 5), Otsego former impoundment (ABSA 7), and the Trowbridge former impoundment (ABSA 8).

Figure 5-4 presents similar values for PCB concentrations in surface soil for all sampled areas. Surface soil is defined here as floodplain sediment/soil taken from the TBSAs, and these samples may in fact represent semi-aquatic sediments that are covered with water for significant portions of the year. Alternative PRGs such as those derived for protection of mink are more appropriate for floodplain sediments that are frequently inundated. This recommended application of PRGs is based on the direct link between these riparian sediments and aquatic and semi-aquatic food webs.

Also included in Figures 5-3 and 5-4 are horizontal lines representing relevant thresholds or PRGs for potential receptors. The threshold or PRG concentrations for both surface soil and floodplain sediment are, from lowest to highest total PCB concentrations, the

- NOAEL-based PRG for great horned owl (2.9 mg/kg)
- NOAEL-based PRG for red fox (5.9 mg/kg)
- NOAEL-based PRG for American robin (6.5 mg/kg)
- LOAEL-based PRG for American robin (8.1 mg/kg)
- LOAEL-based PRG for great horned owl (8.5 mg/kg)
- NOAEL-based PRG for mouse (21 mg/kg)
- LOAEL-based PRG for red fox (29.5 mg/kg)
- LOAEL-based PRG for mouse (63 mg/kg)

Figure 5-3 reveals that maximum total PCB concentrations in floodplain sediments/soils exceed all NOAEL-based PRGs at all sampled locations. Average and U95 total PCB concentrations at all sampled locations exceed all NOAEL-based PRGs except the mouse NOAEL PRG. Average floodplain sediment total PCB concentrations at all three former impoundments (Plainwell, Otsego, and Trowbridge) exceed or nearly equal the LOAEL-based PRGs for great horned owl and robin.

For surface soils (Figure 5-4), limited sampling from TBSAs 1, 3, 5, 10, and 11 reveals greatest potential for concern at TBSAs 3 and 5. Mean, U95, and maximum total PCB concentrations in surface soils at TBSAs 3 and 5 exceed all PRGs except the LOAEL PRGs for mouse and fox. Mean, U95, and maximum total PCB concentrations in surface soils at TBSA 10 exceed or approximately equal the NOAEL PRG concentrations for fox and robin and the LOAEL PRGs for robin and owl. PCBs in surface soils at TBSAs 11 and 1 appear to present little risk to most terrestrial receptors.

Surface soils and floodplain sediments have potential to pose risks to sensitive terrestrial receptors that consume PCB-contaminated invertebrates. Terrestrial omnivores such as mice and terrestrial carnivores such as red fox might be at risk if they forage predominately in floodplain areas that are highly contaminated with PCBs. Foraging outside the floodplain, where surface soil PCB concentrations are lower and less variable than floodplain sediments, is likely to reduce risks to terrestrial omnivores and carnivores. Certain songbirds (e.g., vermivores) foraging within the floodplain are predicted to be at substantial risk because elevated PCB concentrations have been measured in surface soil, floodplain sediment, and most importantly, in earthworms. Onsite PCB risks to most terrestrial biota are expected to be substantially lower than risks to piscivorous birds and mammals. Finally, because some floodplain sediments (including some termed "surface soils") are frequently inundated and support aquatic and semi-aquatic biota, the application of PRGs based on protection of mink should be considered for these locations.

### 5.1.4 Risks from PCBs in Food Items (Ingestion)

Risks to consumers of onsite plants and animals are expected to be highly variable. Only limited site-specific PCB values are available for determining PCB concentrations in site plants. PCBs bioaccumulate in plants to a much lower degree than in animals. However, PCB concentrations in site plants can, based on limited site-specific data and literature soil-to-plant uptake values, be of concern. This is because onsite soil PCB concentrations are sufficiently elevated in some areas to cause elevated PCB concentrations in exposed plants, especially riparian or semi-aquatic plants that grow in aquatic environments or wet soils. It is unknown if the estimated or measured PCB concentration in plants is due primarily to uptake from soil, volatilization from soil, or aerial deposition. Although all three processes have potential to contribute to plant PCB burdens, the dominant process is unimportant to consumers of PCB-contaminated vegetation.

Table 5-1 summarizes the dose estimates from the PCB food web model and presents dose-based LOAELs or Low Effect TRVs ($ED_{25}$) and NOAELs or No Effect TRVs ($ED_{10}$) for representative receptors. Table 5-2 presents ranges (No Effect to Low

Effect) of PCB PRGs for terrestrial receptors (mouse, robin, great horned owl, and red fox). These PRGs are based on NOAELs and LOAELs taken directly from the literature, on calculated $ED_{25}$ and $ED_{10}$ values based on multiple studies from the literature, and on dietary data and site-specific PCB concentrations in floodplain sediment/surface soil.

Table 5-3 presents hazard quotients (HQs) for terrestrial and aquatic biota. HQs for mink, bald eagle, robin, owl, fox, mouse, and muskrat are based on estimated doses from the results of food chain modeling (Appendix C-2).

***HQ = Daily Dose (mg/kg-d) / NOAEL (or $ED_{10}$) or LOAEL or ($ED_{25}$) (mg/kg-d)***

Based on the calculated NOAEC-based HQs, mink are at most risk, followed by bald eagle,, great horned owl, American robin, and red fox. White-footed or deer mouse and muskrat appear to be at little or no risk (HQs<1).

Estimated risks to great horned owls should be viewed with caution, based on the level of PCB contamination in great horned owl eggs collected downstream of Lake Allegan. The apparent discrepancies between egg data and relatively low estimated risks based on food web modeling are discussed in subsequent sections of the ERA.

The types of consumers most likely to be at serious risk at this site are consumers of aquatic prey, especially piscivores. Aquatic biota within the API/PC/KR area, especially carp, are much more seriously contaminated with PCBs than are terrestrial biota that are likely to serve as prey for mostly piscivorous predators such as mink. Mink are at most risk from PCB contamination through ingestion of prey because they

- Consume large amounts fish (with seasonal variation) that are highly contaminated
- Are likely to obtain most or all prey within or near aquatic environments within site boundaries and
- Are the most sensitive to PCBs of all animals studied to date (Eisler 1986)

The maximum allowable tissue concentration for dietary items of mink ranges from 0.5 to 0.6 mg/kg, based on the No Effect $ED_{10}$ and the Low Effect $ED_{25}$ values from the studies described in Appendix D. Mink should be adequately protected if the average PCB concentrations of all prey items contain less than 0.5 mg PCB/kg prey. Prey PCB concentrations greater than 0.5 mg/kg are associated with some degree of risk. When the average PCB concentration in mink prey approaches 0.6 mg/kg, measurable adverse effects are expected. These are primarily adverse reproductive effects that can affect population status.

The calculated $ED_{10}$ and $ED_{25}$ values for mink fall within the range of the dietary NOAELs and LOAELs for total PCBs derived by Heaton et al. (1995) of 0.015 and 0.72 mg/kg. The Heaton et al. (1995) NOAEL is based on a daily dose of 0.004 mg/kg bw-d, while the LOAEL is based on a daily dose of 0.134 mg/kg bw-d. The estimated daily doses of PCBs calculated for mink in this study are 0.091 and 0.11 mg/kg-d (Tables 5-1 and 5-3). The $ED_{25}$ dose is nearly the same value as the LOAEL-based dose derived by Heaton et al. (1995), while the calculated $ED_{10}$ dose exceeds the NOAEL-based dose derived by Heaton et al. (1995).

Estimated doses and corresponding HQs for mink based on food chain modeling are directly related to mink dietary assumptions. Mink diet is expected to vary spatially and temporally, and is likely to differ substantially depending on the predominant foraging areas. Mink foraging along the river are expected to consume more fish and aquatic biota than mink foraging in areas more removed from the river. The latter may consume fewer fish and more birds and small mammals, for example. The fraction of fish in mink diet directly affects the PRGs determined for mink. The mink-based PRGs based on surface water-sediment-fish PCB relationships (presented in Section 4 .2.1) assume a 100% fish diet. PRGs for mink protection would be different (higher) if mink diet was not predominately fish-based. In some cases, food chain modeling can be used to estimate dietary PCB doses. However, food chain modeling based on a highly variable and mostly unknown diet would be associated with considerable uncertainties. Also, the gut contents of the small numbers of mink collected onsite are unlikely to provide much useful information regarding the overall annual diet of mink. Frogs, crayfish, and whole body songbirds, all likely prey of mink, have not been collected onsite and analyzed for PCBs. The assumptions that mink diet is comprised primarily of fish and that fish provide the major source of PCBs to mink are not unreasonable, as discussed below.

U95 PCB concentrations in fish collected from ABSAs 3-9 (the primary areas of impact) range from 0.90 (sucker) to 16.1 mg/kg (carp). Carp collected just downstream of the site, below Allegan Dam, contained up to 36 mg/kg PCBs, and even higher values resulting from long-term monitoring have been recently observed. Where and when readily available, fish are expected to comprise the majority of the diet for mink. This assumption is supported by mink diets for Michigan presented in EPA Exposure Factors Handbook (1993), which suggests that 85 percent of mink diet is comprised of fish.

Fish consumption by certain individual mink, or by most mink during certain seasons, is likely to be supplemented by consumption of mammals, birds, amphibians, reptiles, and invertebrates (e.g., crayfish). Site-specific data are unavailable to assess PCB contamination in crayfish, frogs, and birds, and for this reason food chain modeling based on these dietary items is not performed.

PCB contamination of mammals that may be consumed by mink is expected to vary from low to moderate. PCBs were measured in the whole bodies of muskrat and deer/white-footed mouse and in liver of muskrat. These data are used to estimate doses used to calculate HQs for mink and to support food chain modeling for certain other receptors. Muskrat and mice collected from the API/PC/KR site reveal moderate to relatively low (respectively) whole body PCB concentrations compared to carp. Maximum whole body total PCB concentrations (wet weight) range from 0.28 to 0.45 mg/kg in mice and up to 2.9 mg/kg in muskrat. These potential prey items are, therefore, expected to contribute low (mice) to moderate (muskrat) levels of PCBs to mink diet. Consumption of muskrat by mink could contribute to adverse effects because in some areas whole body PCB concentrations in muskrat exceed the dietary low effect TRV (0.6 mg/kg) derived for mink. However, muskrat are most likely to make up a large portion of mink diet in areas that do not support fish or in winter when fish and crayfish are not as readily available. Consumption of mice by mink is not a major concern because mean whole body PCB concentrations in sampled mice remained well below the dietary thresholds for mink.

Preliminary data on shrews collected onsite suggests that these animals, as expected from their diet, contain substantially greater PCB concentrations than mice or muskrat. Consumers of shrews would therefore be at greater risk than predators eating mice or muskrat. It is not unreasonable to assume some small portion of mink diet is comprised of shrews. Therefore, food chain modeling that bases small mammal consumption on only mice and muskrat probably underestimates PCB dietary exposures.

Fish contamination is also a critical issue for piscivorous birds, such as bald eagle. Avian predators associated with aquatic environments are likely to be exposed to PCBs primarily through ingestion of fish and other aquatic prey. The selected No Effect and Low Effect dose-based TRVs for birds, based on chicken data, are 0.4 and 0.5 mg/kg-d. The calculated dose for bald eagles, based on the food web model and on input parameters presented in Appendices C-1 and C-2, is 2.1606 mg/kg-d. Bald eagles with a diet similar to that presented in Appendices C-1 and C-2 can therefore be adversely affected by PCB contamination. Because this potential risk is based on a diet of 77 percent fish, risks may be reduced where diets include a smaller proportion of fish or where fish are less contaminated than the values used in the food web model. Preliminary site-specific information on the dietary composition of bald eagles suggests that the 77 percent fish value is appropriate for this site.

Table 5-3 also presents HQs for piscivorous wildlife, which are also protective of aquatic biota. One set of HQs for piscivorous wildlife and aquatic biota is based on a comparison of the average of ABSA-specific U95 value for total PCBs in surface water (0.043 ug/L) to the EPA national chronic ambient water quality criterion (AWQC, 0.014 ug/L). The chronic AWQC for PCBs is intended to protect 95% of aquatic species as well as sensitive piscivorous wildlife species. This comparison reveals that PCB concentrations in the Kalamazoo River and Portage Creek surface water have potential to pose risks to piscivorous wildlife (HQ=3.1, Table 5-3). Additional comparisons are made between the same U95 surface water concentration, NOAECs and LOAECs for various fish and invertebrates. This comparison reveals little or no direct risk to fish and invertebrates (HQs<1).

An important goal for the API/PC/KR site is re-establishment of an anadromous salmonid fishery. Toxicity data indicate that salmonids are likely to be among the most sensitive aquatic biota to PCBs (EPA 1980). The re-establishment of a selfsustaining salmonid fishery must, therefore, consider PCB effects on salmonid eggs, larvae, and young as well as effects on adult salmonids and prey species consumed by salmonids. In general, early life stages of fish are more sensitive to contaminants than adults, and reproductive success depends on providing safe exposures for these life stages. Obviously, suitable spawning and rearing habitats must also be present if a self-reproducing fishery is to become established in the Kalamazoo River.

### 5.1.5 Reproductive Risks to Birds (Bird Egg Data)

Many bird eggs have been collected within the site boundaries within the past several years. Most of these were collected from 1993 through 1996. These data are summarized on Table 4-5b, and are used to calculate egg-based HQs. Tables 5-4.a and 5-4.b provide comparisons of egg-based NOAECs and LOAECs for total PCBs to PCB data for birds eggs collected onsite from 1993 to 1996. These comparisons are presented as hazard quotients (HQs) where bird egg PCB concentrations are divided by NOAECs or LOAECs for bird eggs.

Egg-based HQs are calculated using two sets of relevant egg-based toxicity data. First, PCB concentrations in eggs collected onsite are compared to egg-based toxicity values from Table 4-10, resulting in the HQs shown on Table 5-4.a.. The toxicity data shown on Table 4-9 are associated with adverse reproductive effects due to PCB contamination of bird eggs. As noted on Table 4-10, for most tested species, total PCB concentrations in bird eggs ranging about 1 to 2 mg/kg are associated with no adverse effects. Unacceptable adverse effects have been observed in most species at egg concentrations ranging from about 3 to 6 mg/kg. Chickens appear to be among the most sensitive species to PCBs, while Forster's tern appears to be among the most resistant.

Second, PCB concentrations measured in bird eggs collected onsite are compared to egg-based NOAECs and LOAECs derived using the $EC_{10}$ and $EC_{25}$ approach detailed in Appendix D. The HQs resulting from these comparisons are presented on Table 5-4.b, and in general exceed the HQs derived using the toxicity data presented on Table 4-10. These exceedences are likely due to due the sensitivity of chickens to PCBs, and this sensitivity underlies the TRVs derived using the $EC_x$ approach detailed in Appendix D.

Although there are differences in the HQs depending on the source of the toxicity data used (Table 4-10 or Appendix D), the general trends remain the same. The data presented on Tables 5-4.a and b. reveal a wide range of risk estimates (HQs) based on PCB contamination of bird eggs collected onsite. The magnitude of HQs appears directly related to diet. Average PCB contamination of eggs of *piscivorous* birds (bald eagle, great blue heron) is the highest (bald eagle) or among the highest (great blue heron). *Carnivorous* raptors such as red tailed hawk and great horned owl are also associated with elevated PCB contamination of eggs. These species are presumed to feed primarily on terrestrial rodents and birds. *Omnivorous* birds such as robins are associated with moderate risks based on degree of PCB contamination of eggs. PCB contamination of eggs of *insectivorous* birds (e.g., yellow warbler, red winged blackbird, wood thrush) appears low but possibly significant (HQs range from less than 1.0 to 1.9). Finally, *herbivorous* waterfowl, represented by wood duck, appear to be at low risk based on low levels of PCB contamination in eggs. In summary, PCB contamination of bird eggs can be approximated as follows:

***Piscivores > Carnivores > Omnivores > Insectivores > Herbivores***

Most of the risk estimates presented on Tables 5-4.a. and b. are more or less expected, given the measured or estimated degree of PCB contamination in dietary items such as fish, rodents, and earthworms. However, the high HQs of red tailed hawk and especially those of great horned owl are unexpected.

PCB contamination of expected major prey items of great horned owl, such as white footed or deer mice, is low, based on measured whole body PCB concentrations in these species collected onsite. PCB contamination of songbirds, the other likely prey item of great horned owls based on dietary studies in Michigan (Appendix C-1), are predicted to be quite high for whole body songbirds based on the selected diet-to-carcass BAF (Appendix C-1). It is currently unclear if great horned owls are obtaining much of their total PCBs from songbirds or from some other unidentified source.

Other potential dietary sources of PCBs to great horned owls include prey with stronger associations with aquatic environments. These may include muskrat (which are associated with moderate levels of PCB contamination), shrews (which appear to have higher PCB concentrations than mice or muskrat based on preliminary data), waterfowl, fish carcasses, other small mammals such as young raccoons or mink, crayfish, and frogs. The aquatic-associated prey items are not expected to be major components of great horned owl diet, but local diet along the river corridor may differ from what is generally expected or reported in the literature.

In summary, there does not appear to be a clear link between PCB levels in floodplain sediments or soils near the nests where owl eggs were taken and the elevated levels of PCBs in owl eggs. For example, eggs taken downstream of Lake Allegan contained PCBs in the range of about 16 to over 90 ppm, yet floodplain sediments in this area remain low, generally less than 1 ppm. Since the primary route of exposure of great horned owls to PCBs is poorly understood at this site, protection of great horned owls and other similar birds should not be the basis of PRGs for floodplain sediment or surface soil.

### 5.1.6 Sitewide Summary of Risks

Table 5-3 presents the results of a simplified HQ approach (e.g., exposure concentration/effects concentration) that presents risk in a very general manner for representative receptors. This table presents the estimated risks for all representative species of concern based on estimated PCB dose (birds and mammals) or on the sitewide average of U95 SW PCB concentration (aquatic receptors). For risks based on surface water exposure, the risk estimates consider only the direct potential toxicity to exposed receptors. Risks to aquatic biota resulting from bioaccumulation are not included. Risks to birds and mammals are based on estimated PCB dose compared to no effect and low effect doses from the literature or calculated using the $ED_x$ approach discussed previously (and discussed in detail in Appendix D).

The risks presented on Table 5-3 are based on sitewide averages of (1) U95 total PCB concentrations for abiotic media and fish, and (2) maximum total PCB concentrations for sampled terrestrial biota serving as input to food chain modeling (earthworms, mice, muskrat). These exposure concentrations are used to describe reasonable upper bound exposures across the entire site. For most species or individuals, these risks probably over-estimate actual risks in relatively clean areas. Similarly, these risks are probably under-estimated for highly contaminated areas, often described as "hot spots". Sitewide average risks are therefore unlikely to be highly useful for evaluating location-specific contamination.

## 5.2 Risks from Nonchemical Stressors

The major non-chemical stressors contributing to biological impairment of the Kalamazoo River are disturbed aquatic and terrestrial habitats. Disturbances of aquatic habitat appear to be primarily caused by conditions related to urban environments and sediment inputs from upstream sources and streambank erosion. Impacts from urbanization may include degradation of streambanks, flow alterations, channelization, etc. Deposition of fine-grained sediments often results in the loss or degradation of preferred habitats for most desirable benthic macroinvertebrates. Spawning areas for many fish species would also be similarly affected where deposition of fine-grained sediments predominates. Also, certain fish species would be indirectly affected by conditions that impaired the colonization, survival, growth, and reproduction of prey species, including benthic macroinvertebrates.

Finally, fine-grained sediments commonly contain higher concentrations of chemicals than coarser materials. Fine-grained sediments within the Kalamazoo River channel are expected to be more toxic to aquatic life than large grained sediments because of increased sorption of PCBs on fine-grained materials. Sedimentation in the Kalamazoo River is, therefore, a source of both physical (habitat disturbance) and chemical (PCB toxicity) stress on resident aquatic biota.

Terrestrial/upland habitats are also disturbed in some areas. This disturbance includes long-term impacts related to urbanization and more temporary impacts in some areas related to remedial activities. Also, the physical presence of PCB-contaminated surface soils and deposited sediments, and the toxic conditions associated with these media, preclude the maintenance of a diverse and healthy plant community in some cases. Physical or chemical stressors that impair the establishment and/or maintenance of vegetative growth can adversely affect animals that require sufficient food (herbivorous species) and cover (most all species) for survival and reproduction. Sensitive soil-dwelling animals, along with sensitive plant species, are not expected to inhabit areas where PCB contaminated media substantially replaces or covers native soils. The expected decrease in abundance and diversity of soil biota, including important microorganisms critical to nutrient recycling, can be due to both physical (displacement or covering of native soil) and chemical (toxicity) causes. As stated previously, PCB-contaminated streambank sediments/surface soils are also likely to contribute to impairment of the Kalamazoo River through erosion and runoff.

# 5.3 Risk Summary and Ecological Significance

Section 5.3.1 summarizes the risks for this site. The ecological significance of these risks is also included in this summary. The risk summary is followed (Section 5.3.2) by other observations or information that contributes to the multiple lines of evidence presented in the ERA.

## 5.3.1 Risk Summary

Table 5-3 presents the summary of risks for all representative ecological receptors based on doses (terrestrial receptors) or direct toxicity (aquatic receptors). Figures 5-5 and 5-6 present total PCB concentrations in terrestrial biota and fish, respectively, for sampled locations. Figures 5-7, 5-8, and 5-9 present the mean, U95, and maximum whole body total PCB concentrations measured in smallmouth bass, carp, and suckers, respectively. These values are overlaid with the calculated no effect ($EC_{10}$) and low effect ($EC_{25}$) dietary concentrations associated with critical reproductive effects in mink.

The risks from the sitewide representation presented in Table 5-3 are considered in addition to the location-specific distribution and concentration of PCBs described in previous sections (e.g., Table 4-5) and presented in part of Figures 5-5 and 5-6. The data presented in Figures 5-7, 5-8, and 5-9 are also used to describe important risk-related information. Together this information is used to summarize risks in the following discussion.

- Most aquatic biota such as invertebrates and fish are unlikely to be adversely affected by direct contact with and ingestion of surface water because of relatively low PCB toxicity to most aquatic biota. Adverse effects may be exhibited by sensitive aquatic biota such as some species of aquatic plants, but such effects are likely to be spatially and temporally limited.

- PCB contamination of surface water and streambed sediment (and floodplain sediment that is frequently inundated or has potential to erode into the river) is likely to adversely affect sensitive piscivorous predators such as mink through consumption of PCB-contaminated prey, especially fish.

  - Impaired reproduction of mink and ultimately decreases in mink populations are the most likely effects of PCB contamination in aquatic prey. Henry, et al. (1998) demonstrated that concentrations of PCBs in smallmouth bass from a remote lake in the Upper Peninsula of Michigan were of concern to mink populations, even with the low levels of PCBs in fish tissue from this lake.

- Other piscivorous predators, such as bald eagles, also appear to be at high risk based on the exposure assumptions presented in Appendices C-1 and C-2. The level of PCB contamination in eagle eggs suggests that these assumptions are valid. Furthermore, field investigations of bald eagles by U.S. Fish and Wildlife indicate there has been a loss of reproductive capacity and decrease in the populations of bald eagles within the site boundaries.

■ Terrestrial and semi-aquatic biota may be at risk from PCB-contaminated floodplain sediment and surface soil, depending on life history (e.g., foraging behavior, diet, mobility) and sensitivity to PCBs.

- Omnivorous birds (represented by the robin) that consume substantial numbers of soil invertebrates, such as earthworms, appear to be at moderate but significant risk.

- Carnivorous terrestrial species (represented by the red fox) are unlikely to be at significant risk unless foraging is concentrated in riparian areas with contaminated floodplain sediment and diet consists of prey that (1) reside in PCB-contaminated areas, and (2) have taken up substantial amounts of PCBs.

- Omnivorous terrestrial species (represented by mice) are also unlikely to be at significant risk unless they reside in the most contaminated areas. PCB uptake in mice appears to be low.

- Semi-aquatic herbivorous mammals (represented by muskrat) may be at risk from PCB contamination because estimated dietary doses exceed recommended threshold values for rats. This conclusion is based on the assumption that laboratory rats and muskrats are equally sensitive to PCBs via ingestion. Muskrats contaminated with PCBs may also cause adverse effects to muskrat predators because some muskrats contain PCBs in excess of recommended dietary limits for PCB-sensitive predators such as mink.

### 5.3.2 Other Supporting Information

This section presents a compilation of qualitative findings, anecdotal information, and observations that support the risk estimates presented in this ERA. This information by itself cannot be used to derive risks or characterize the site in any particular way. However, the following information is considered useful to add to the multiple lines of evidence presented in this ERA. The following is therefore intended to support the conclusions and assumptions presented and discussed in this ERA.

- Yearling smallmouth bass (<8 months old) had whole body PCB concentrations exceeding 3 mg/kg, well above the calculated dietary low effect concentration to protect mink (0.6 mg/kg)

- Mink trapping success was inversely correlated to level of PCB contamination at TBSAs

  – Habitats were similar at all locations, based on both qualitative assessments by local trappers and on preliminary data from quantitative habitat assessments conducted by MSU

  – Equal trapping time was expended at each location

- Bald eagles at the Allegan State Game Area have had very poor reproductive success (Best 1999)

  – Since monitoring began in 1960, two fledged young have been produced in 15 breeding attempts (0.13 fledged young per occupied breeding area – 0.7 is indicative of stable population) (Best 1999)

- Great horned owl eggs from the Allegan State Game Area contained up to 90.8 mg/kg total PCBs

- Redtail hawk eggs from the Allegan State Game Area contained up to 27.1 mg/kg total PCBs

- Eggs of other bird species from the Allegan State Game Area contained low to moderate levels of PCBs

- Previously observed great blue heron colony alongside Kalamazoo River is gone, and heron eggs from the Allegan State Game area contained PCBs at concentrations averaging over 10 mg/kg (max over 40 mg/kg)

- Regional bald eagle sightings reported to MDNR have all been from alongside the Kalamazoo River within the site boundaries

  – This supports the use of 1.0 for a SFF for bald eagles

- Non-normalized average BSAFs for other sites in the Great Lakes region consistently range from a little less than 1 to about 2

  – Average BSAFs for this ERA range from 0.28 to 1.9, with an overall average of 1.02

- Muskrat and mink liver PCB concentrations (mg/kg wet weight) support the conclusion of significant exposure to PCBs.

- Maximum PCB concentrations in muskrat liver range from non-detect (ABSA 1, reference) to 1.2 mg/kg (Trowbridge).

- Maximum PCB concentrations in mink liver range from 1.5 mg/kg (ABSA 1, reference) to 12.5 mg/kg (ABSA 10, Allegan).

Figures 5-10 through 5-13 show the concentrations of total PCBs in muskrat whole body (Figure 5-10), muskrat liver (Figure 5-11), mink whole body (Figure 5-12), and mink liver (Figure 5-13). These concentrations are shown as both wet weight and lipid weight values. LOAELs, NOAELs, or other effects type data are unavailable for comparisons to whole body mink or muskrat PCB concentrations or to muskrat liver concentrations.

However, the level of PCB contamination of mink liver collected onsite can be compared to NOAELs and LOAELs based on mink liver PCB concentrations. For example, Kannan et al. (2000) derived (from other studies) a lipid-normalized mink liver total PCB NOAEL of 2.03 mg/kg, lipid weight, and a LOAEL of 44.4 mg/kg, lipid weight. Based on lipid-normalized values, total PCB concentrations in liver in the eight mink collected to support this ERA range from 2.25 to 57.51 mg/kg, lipid weight. The range for background locations (n=5) is 2.25 to 5.17 mg/kg lipid weight. For Plainwell the single mink liver collected contained 11.26 mg/kg lipid weight. The single value for Trowbridge equals 17.02 mg/kg lipid weight. Finally, the two mink livers collected at Allegan contained 11.38 to 57.51 mg/kg lipid weights.

Figure 5-13 shows these lipid-normalized mink liver PCB concentrations as well as the same values expressed as wet weight concentrations. This figure reveals that all mink livers (lipid wt.) collected onsite exceed the lipid-normalized mink liver NOAEL presented by Kannan et al. (2000). The LOAEL of 44.4 mg/kg total PCBs, lipid weight, was exceeded by one of the livers collected at Allegan. The mink livers collected at the background locations slightly exceed the NOAEL, while all others from Plainwell, Trowbridge, and Allegan exceed the NOAEL by about five-fold (Plainwell and one Allegan sample), eight-fold (Trowbridge), or 26-fold (second sample at Allegan).

The small sample sizes (n=1 to 5 at any location) precludes using these liver data to make definitive statements regarding risks to mink, but they appear to support the overall conclusions regarding mink exposure and risk from PCBs at this site. This conclusion is based in part on the finding that all mink livers collected from the site contained total PCBs at levels exceeding the liver-based NOAEL and approaching (or in one case exceeding) the liver-based LOAEL.

Finally, the large spread between the lipid-normalized liver NOAEL (2.03 mg/kg) and LOAEL (44.4 mg/kg) adds uncertainty to the actual threshold concentration at which adverse effects would begin to be observed in exposed mink. The values of the NOAEL and LOAEL calculated by Kannan et al. (2000) are a function of the treatment concentrations used in the original studies. Additional studies with treatment concentrations closer to one another may reveal that the actual LOAEL is lower than the LOAEL of 44.4 mg/kg reported by Kannan et al. (2000).

## 5.4 Uncertainty Evaluation – Risk Characterization

By definition, uncertainties in risk characterization are influenced by uncertainties in exposure assessment and effects assessment. Uncertainties in exposure assessment are reduced by the adequate sampling and analysis of surface water, streambed sediment, floodplain sediment, surface soil, and biota. Descriptions of the magnitude and distribution of PCBs within the API/PC/KR site are considered to be representative of current conditions because of the environmental persistence of PCBs.

Effects data can also contribute to overall uncertainty in risk characterization. Science and scientific investigations cannot prove any hypothesis beyond doubt. The scientific method is instead based on stating hypotheses, testing these hypotheses, and either accepting or rejecting the hypotheses based on the weight-of-evidence provided by test data. Cause and effect relationships can be inferred, and evidence can support hypotheses, but cause and effect relationships can rarely be proven.

In this ERA, the primary null hypothesis is that the Kalamazoo River and associated aquatic and riparian habitats have not been and are not being adversely affected by PCBs and related physical stressors. These stressors are assumed to have originated primarily from past industrial activities along the Kalamazoo River. This null hypothesis is tested by using multiple lines of evidence, which provide support for either rejection or acceptance of the proposed hypotheses. No data are conclusive. Site-specific biological and chemical data are subject to concerns of representativeness and availability and the sensitivity of sampled species used to derive such data. Toxicity data that are not site specific may not be totally applicable to the site being investigated. There are concerns about laboratory-to-field extrapolation of effects data. Taxa-to-taxa extrapolations are a concern as well. All effects data are, therefore, subject to some degree of uncertainty. Confidence in the ability of selected effects data to assess potential for ecological risks varies for each data value selected.

This ERA presents effects data in the risk characterization phase that be used to assess potential for adverse ecological impacts. While each and every effects data value used in this and every other ERA is associated with some degree of uncertainty, it is the general trend described by the comparisons between exposure concentrations and effects concentrations, and the overall confidence in such comparisons, that are most important.

Another potential source of uncertainty is the lack of extensive biological or ecological surveys conducted over time to support this ecological risk assessment. The types of surveys needed to aid in the determination of cause and effect relationships are highly dependent on data quality and data quantity. For example, historical data on fish and furbearer populations could be used to evaluate population-level effects over time that might be associated with PCB contamination or other sources of ecological stress. Other useful long-term data such as gut contents of key predators (e.g., mink) could help refine the estimated average dietary composition critical to food chain modeling. In contrast, the gut contents of a few mink taken during one season cannot be used to reliably estimate the average annual diet of mink. For the most part, these types of long-term data are not currently available. Still, observations based on recent fieldwork can be used to provide important qualitative information and in some cases evidence of adverse impacts.

For example, trapping success of mink appears to be associated with PCB contamination in sediment and fish. While equal trapping effort was expended at all locations, trapping success was substantially greater within the reference areas upstream of the API/PC/KR site. Of the 10 mink collected for tissue analyses, 5 (50 percent of total) were taken from the upstream reference area (ABSA 1). Of the remaining 5 mink, 1 was taken from ABSA 6 upstream of Otsego City Dam, 2 from TBSA 5 upstream of Trowbridge Dam, and 2 from ABSA 10 downstream of Allegan Dam. Although data are insufficient for making conclusions relating cause and effect of possible population level effects on mink, it is noted that fish tissue PCB concentrations are correlated with numbers of mink collected. Substantially fewer mink were collected within and downstream of the API/PC/KR where fish tissues contained the highest levels of PCBs. Similarly, fish tissue PCB concentrations were substantially lower in areas where mink trapping was highly successful.

The risk characterization method itself can also contribute to uncertainty. This type of uncertainty is minimized by not relying on a single exposure point concentration (e.g., mean or maximum value) or on a single effects concentration (e.g., AWQC or $LC_{50}$). The multiple lines of evidence used to conduct this ERA provides a more meaningful approach that minimizes the effects associated with the inherent uncertainty in any particular exposure or effects data value. This can be best demonstrated with the selection of TRVs for mink and non-raptor birds. For these receptors, multiple studies were evaluated and the final TRVs were determined using an approach ($EC_x$ or $ED_x$) that incorporates data from several studies determined to be most appropriate. This approach is in contrast to the more common method where multiple studies are evaluated and one value is selected from a single study to serve as the TRV of choice.

Uncertainties with risk characterization differ for each receptor or receptor group. For example, risks to great horned owl and red fox are likely to be overestimated because these risks are based in part on the consumption of songbirds, represented by robin. Granivorous bird species and others that do not consume earthworms are likely to have much less exposure to PCBs than robins. Using robins as a representative avian prey item for owls and foxes is therefore likely to result in an overestimation of risks.

This ERA presents overwhelming evidence that, despite uncertainties identified in the ERA, two and possibly three of the four proposed null hypotheses introduced in Section 3.4 and presented below can be rejected with little reservation.

1. *The levels of PCBs in water, sediment, and biota are not sufficient to adversely affect the structure or function of the fish populations in the Kalamazoo River and Portage Creek System.*

This hypothesis is *accepted* because there is no direct evidence that fish communities are being affected by PCB contamination. The impaired fish community of Lake Allegan is comprised primarily of stunted and often malformed carp. The cause of these findings cannot be determined from the available data. It is noted, however, that PCBs cause a wasting syndrome in several mammalian species. There is insufficient evidence to determine if similar effects are occurring in fish.

2. *The levels of PCBs in water, sediment, and biota are not sufficient to adversely affect the survival, growth, and reproduction of plant and animal aquatic receptors utilizing the Kalamazoo River and Portage Creek system.*

This hypothesis is *conditionally rejected*. This is based on the finding that at some locations the maximum detected surface water PCB concentration exceeds the lowest chronic value for freshwater fish, invertebrates, or aquatic plants.

3. *The levels of PCBs in water, sediment, and biota are not sufficient to adversely affect the survival, growth, and reproduction of mammalian receptors utilizing the Kalamazoo River and Portage Creek system.*

This hypothesis is *rejected* because there is sufficient evidence that adverse effects are likely to be experienced by mammalian predators, especially those that consume fish.

4. *The levels of PCBs in water, sediment, and biota are not sufficient to adversely affect the survival, growth, and reproduction of avian receptors utilizing the Kalamazoo River and Portage Creek system.*

This hypothesis is *rejected* because there is sufficient evidence that adverse effects are likely to be experienced by avian predators, especially those that consume fish.

In summary, the ecosystem associated with the API/PC/KR portion of the Kalamazoo River has been and is currently being adversely affected by PCBs originating from past industrial activities. The environmental persistence of PCBs suggests that adverse impacts to ecological resources at this site will continue into the foreseeable future without significant remedial/removal actions.

## 5.5 Remediation Issues

The Kalamazoo River and nearby riparian areas are currently being adversely affected by nonpoint sources of chemical contamination. It is expected that remediation of the most serious and most ubiquitous contaminants (i.e., PCBs) would result in remediation of other less serious contaminants that are not as uniformly distributed or are present at lower concentrations. For this reason, this preliminary discussion of remediation issues is focused on remediation of PCBs in aquatic and terrestrial media.

Instream and floodplain sediments, surface water, surface soil, and biota within the API/PC/KR site are contaminated with PCBs. Contaminated groundwater may discharge to the Kalamazoo River and Portage Creek as well, but groundwater inputs have not been quantitatively evaluated. It is expected that the most critical current nonpoint source of PCBs to the Kalamazoo River and Portage Creek are erosion and runoff of contaminated streambank sediments/soils and release of PCBs from streambed sediments to surface water. Surface water within the API/PC/KR area is probably also affected by upstream, offsite inputs of both contaminated surface water and contaminated sediments, but such inputs appear to be small compared to onsite sources (e.g., areas of former impoundments). Again, contaminated groundwater may contribute to elevations in surface water PCB concentrations during certain times of the year and in certain locations, depending on groundwater/surface water relationships. Fine-grained instream sediments probably move downstream at a rate dependent on flow. During and immediately following storm events, fine grained sediments are likely to move downstream rapidly, eventually entering depositional areas within the API/PC/KR site or Lake Michigan. Lake Michigan probably acts as a sediment trap for sediments that reach far downstream. Several areas of the API/PC/KR site are likely to trap substantial amounts of fine-grained sediment, and removal of fine-grained sediment from these depositional areas is likely to decrease biological impairment by removing a primary source of toxicity and instream siltation.

Stabilizing streambank materials is also expected to decrease the potential chemical and physical effects of erosion. Surface water concentrations of PCBs are unlikely to return to safe levels without consideration of both streambank and streambed sediments. Siltation must be controlled if a diverse and healthy aquatic community is to be established in affected areas of the API/PC/KR site. Removal and/or capping of streambank sediments contaminated with PCBs is necessary to prevent erosion and runoff which ultimately contaminates and physically degrades the river.

Finally, the use of a single sitewide cleanup value for sediments is supported by the dynamic nature of the sediment environment. A single protective value derived for the entire site assumes that conditions can and do change both seasonally and from year to year, while multiple values assumes stable conditions at each location where a separate cleanup value may be derived. Since sediments are unstable and are continuously moving into the aquatic environment and downstream, the use of multiple ABSA-specific or other location-specific cleanup values is unwarranted.

Table 5-5 presents a compilation of total PCB limits, criteria, and site-specific PRGs proposed to be considered in the selection of a single media-specific cleanup value for the API/PC/KR site. For each media type, the selection of indicator chemicals is appropriate. That is, remediation of the most critical chemical component within each media type (e.g., PCBs) is likely to result in remediation of the less critical chemical stressors as well. Total PCBs can, therefore, serve as indicator chemicals for remediation purposes.

For surface water, control of streambank erosion and runoff and elimination or decrease in streambed sediment volumes and/or PCB concentrations is most critical. For streambed and streambank sediment, substantial decreases in total PCBs are warranted because these media will continue to provide a toxicant source to the Kalamazoo River and resident aquatic and terrestrial biota. For surface soil, concentrations of PCBs need to be substantially reduced where such soils have potential to erode into aquatic environments.

The selection of the most appropriate methods for achieving remediation goals is not a risk assessment issue but is a risk management issue to be addressed in the feasibility study (FS) for the API/PC/KR site. The application of specific PRGs is also considered a risk management decision. This risk assessment derives and recommends a range of receptor- and media-specific PRGs. It is most appropriate for risk managers rather than risk assessors to decide how to best apply these PRG ranges to meet remedial goals and objectives.

## 5.5.1 Summary of Recommended Cleanup Values

Table 5-5 summarizes the proposed cleanup levels for various media for the Kalamazoo River Superfund Site. This summary is based on the Low Effect PCB concentrations calculated for site media, and as such are analogous to “not to exceed” concentrations.

- *Surface water* total PCB concentrations should not exceed 0.00197 μg/L to protect mink, the most sensitive of all animals tested to date. This is based on the low effect dietary concentration ($EC_{25}$) determined from long-term studies in which mink were fed PCB-contaminated fish and on site-specific BAFs for fish. The corresponding No Effect PCB concentration is 0.0016 ug/L.

- *Streambed sediment* total PCB concentrations should not exceed 0.6 mg/kg to protect mink, the most sensitive of all animals tested to date. This is also based on the low effect dietary concentration ($EC_{25}$) determined from long-term studies in which mink were fed PCB-contaminated fish, site-specific BAFs for fish, and sediment/water relationships. The corresponding no effect dietary concentration ($EC_{10}$) to protect mink is 0.5 mg/kg.

- *Surface soil* and in some cases *floodplain sediment* PCB concentrations should not exceed 8.1 mg/kg (low effect PRG based on $ED_{25}$) to protect omnivorous birds such as American robin. The corresponding no effect PRG (based on $ED_{10}$) for robin is 6.5 mg/kg.

**Figure 5-1**
**Total PCB Concentrations - Thresholds/Criteria**
**API/PC/KR Surface Water**

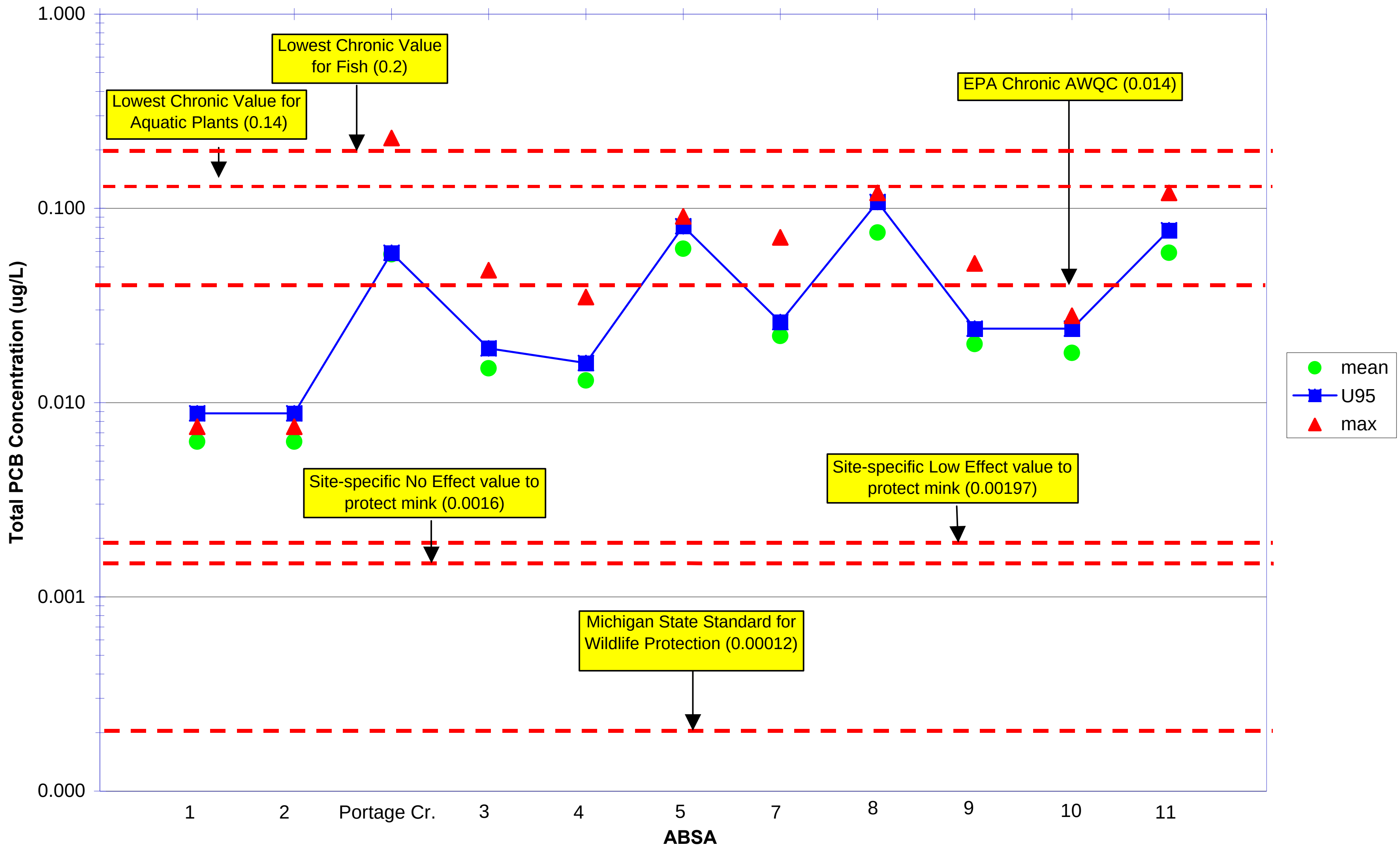



FIG5-1_Rev42303.XLSfig5-1sw

**Figure 5-2**
**Total PCB Concentrations - Thresholds - PRGs**
**API/PC/KR Instream Sediment**

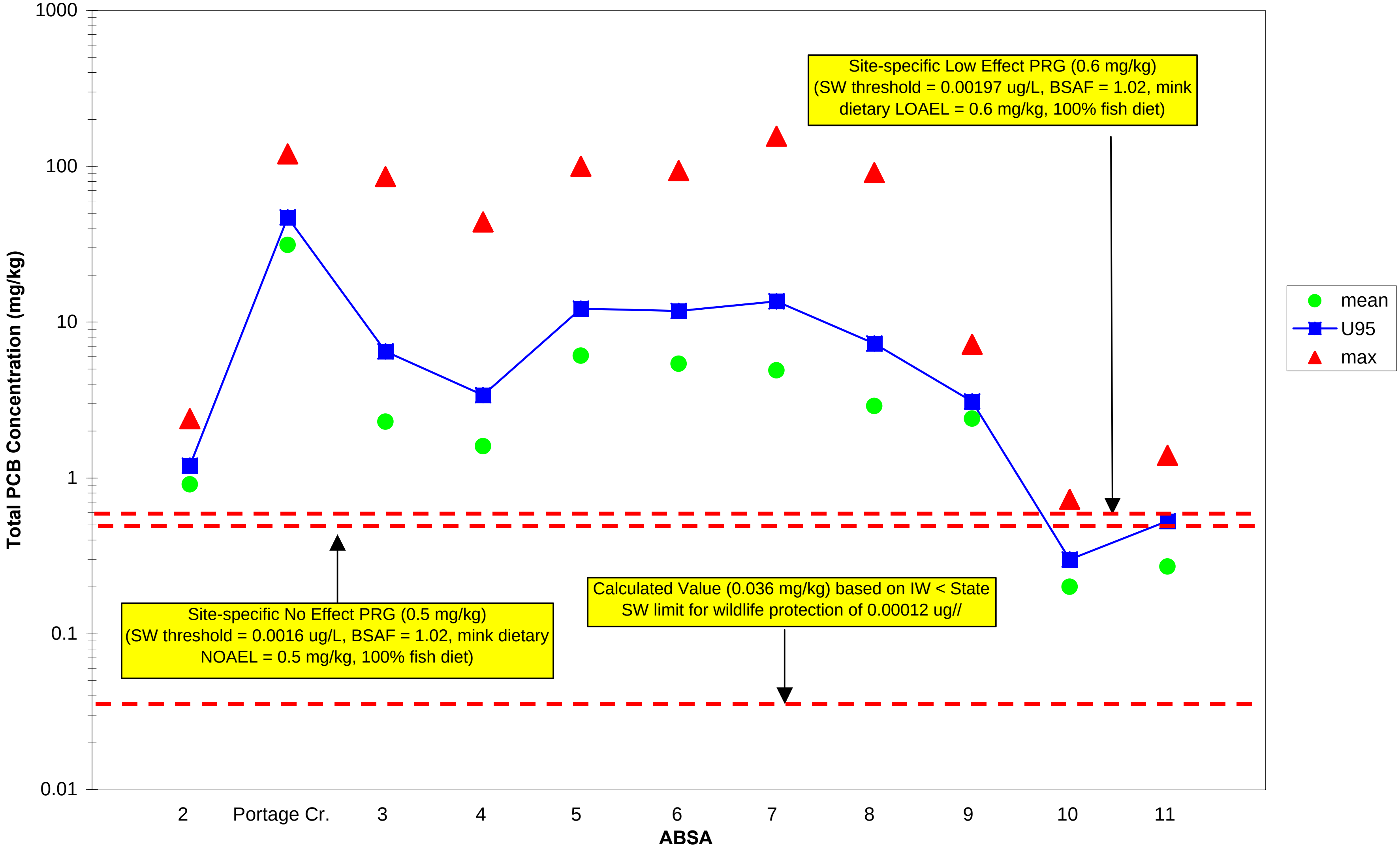



FIG5-2-4_Rev042303.xlsfig5-2sed

**Figure 5-3**
**Total PCB Concentrations - PRGs**
**API/PC/KR FP SED/SS (Terrestrial/Floodplain Exposures)**

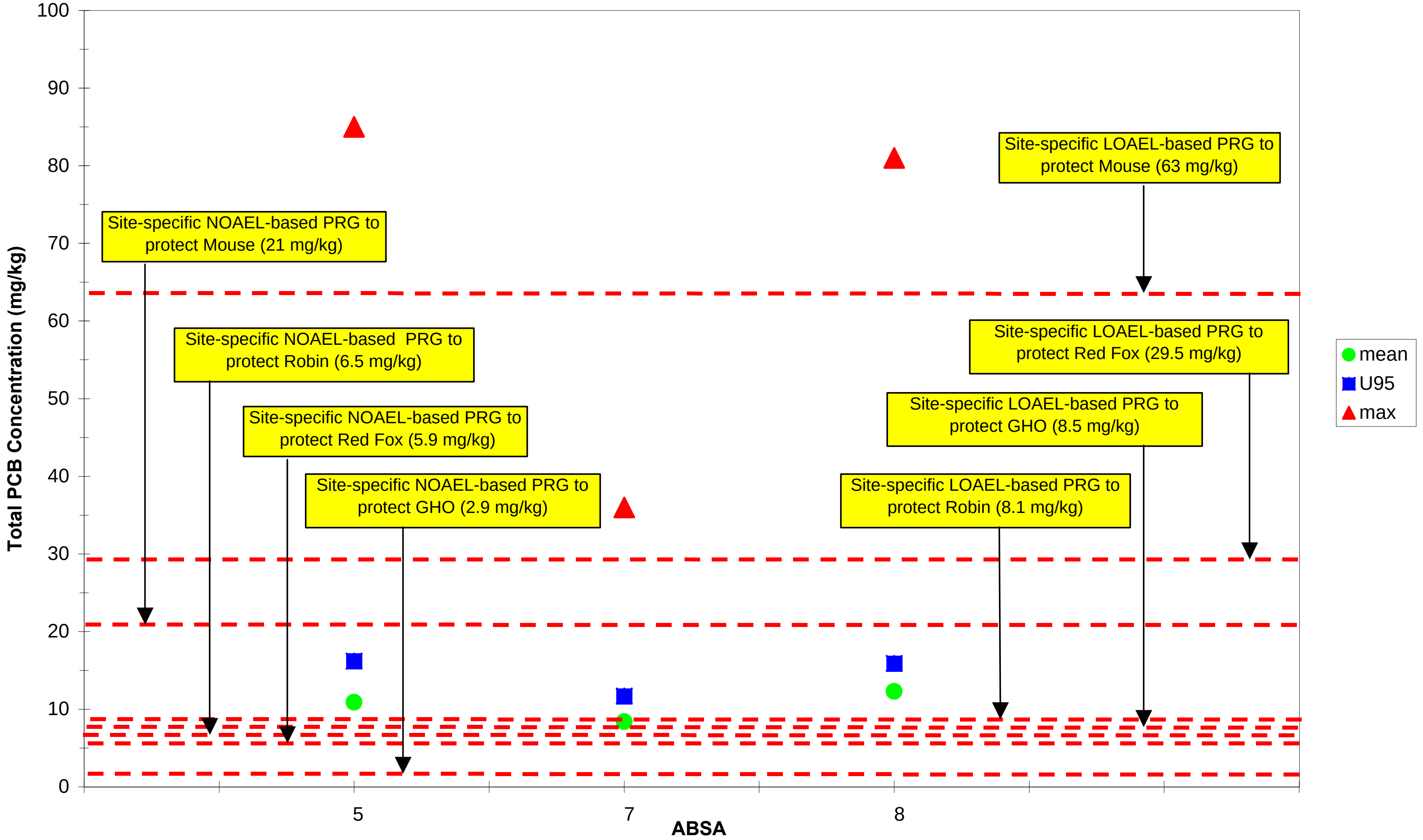



FIG5-2-4_Rev042303.xlsfig5-3fpsed

# Figure 5-4
## Total PCB Concentrations - PRGs
## API/PC/KR FP TBSA Surface Soil (Terrestrial Exposures)

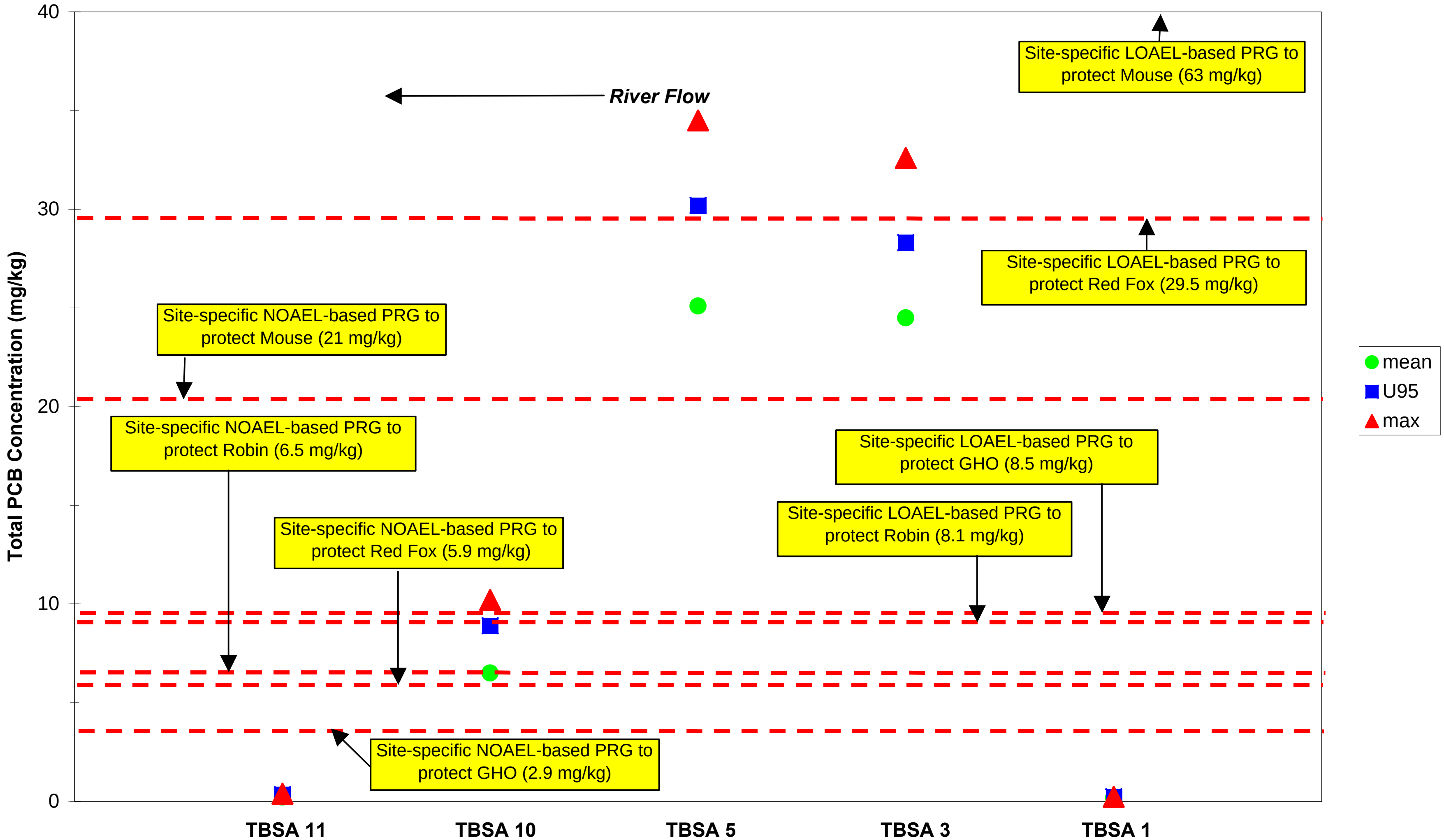



FIG5-2-4_Rev042303.xlsfig5-4ss

## Figure 5-5
## Maximum Total PCB
## Concentrations in Terrestrial Biota

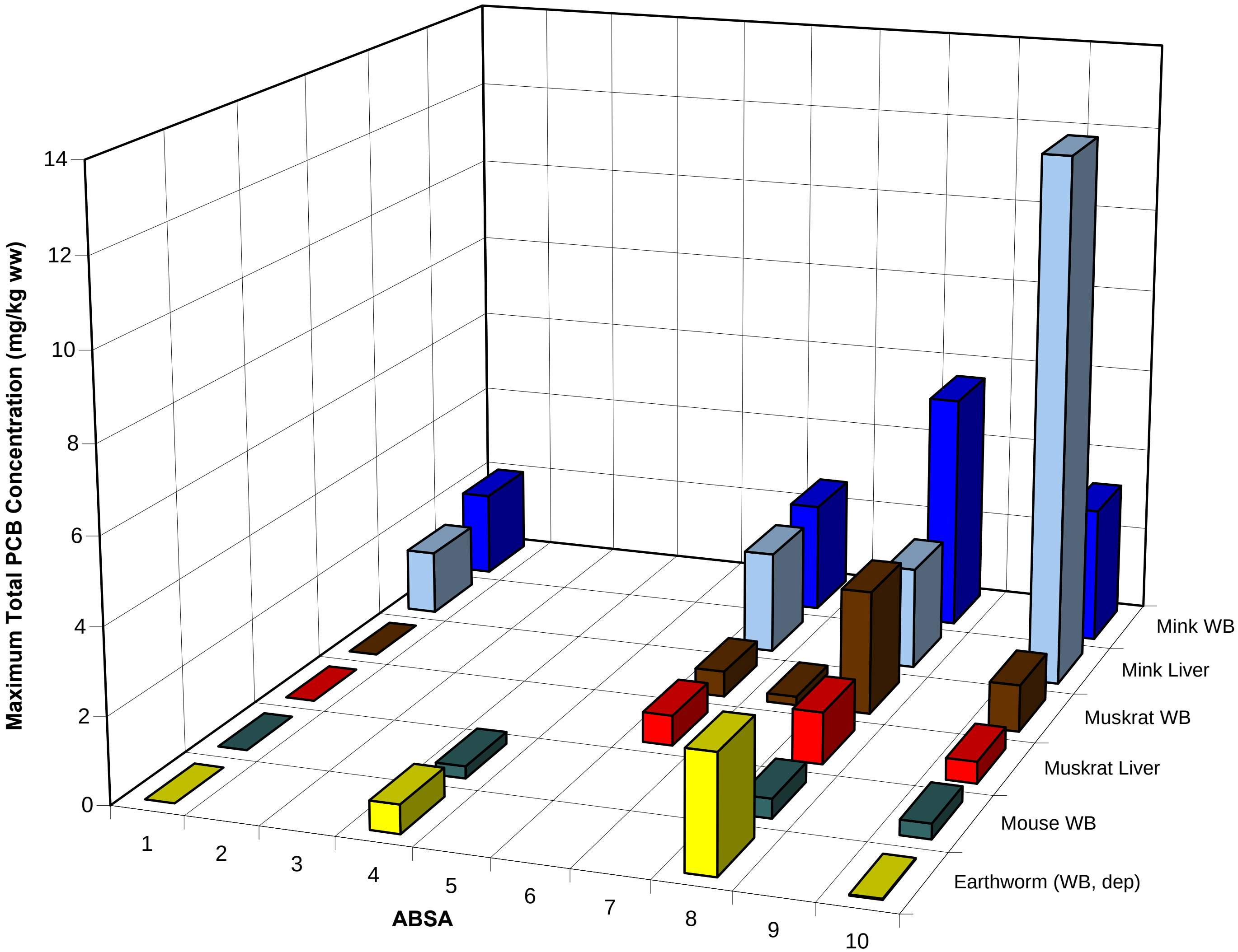



FIG5-5-6_Rev120402.XLSfig5-5terr

Figure 5-6
U95 Whole Body Total PCB
Concentrations in Fish

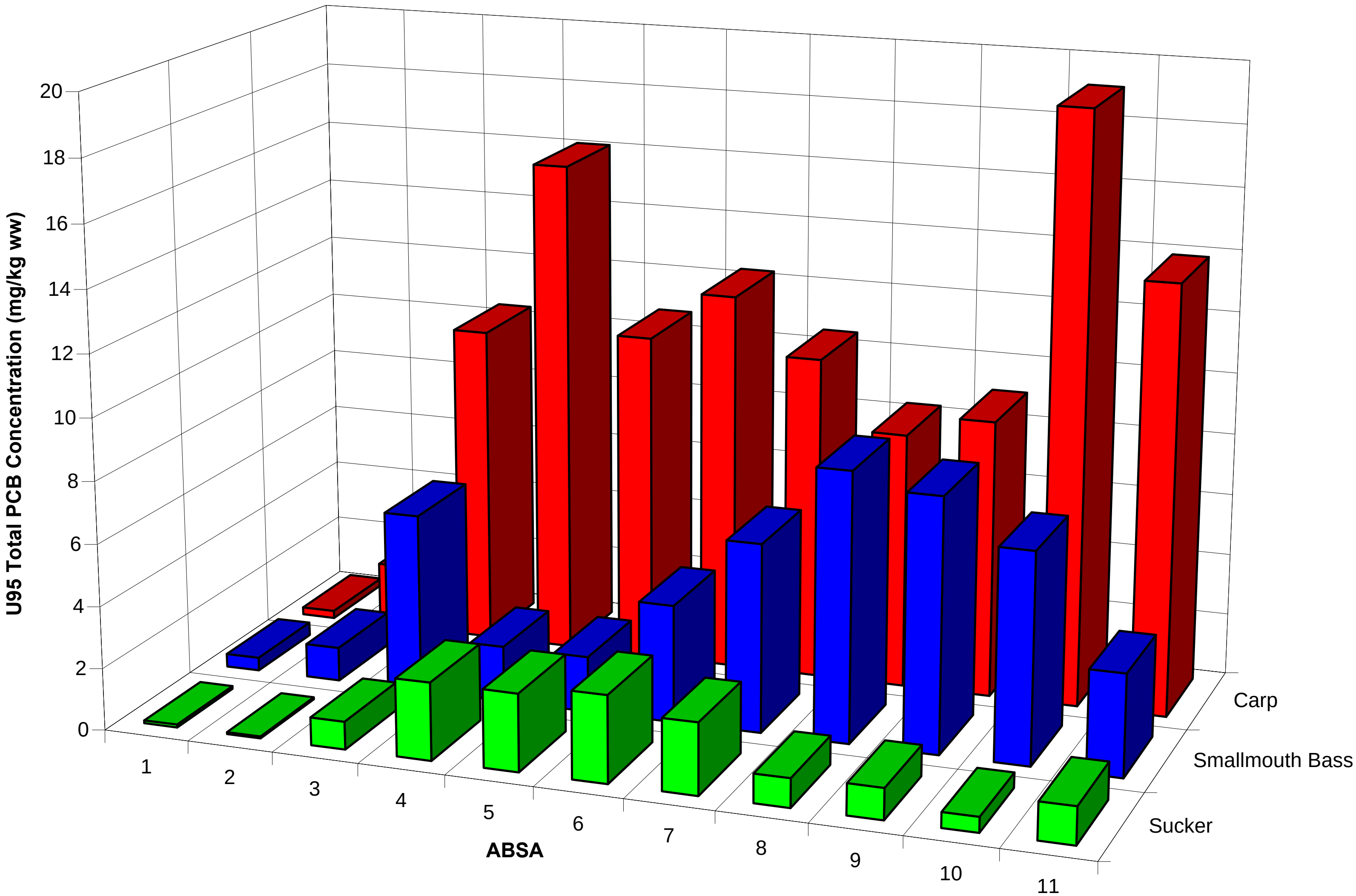



FIG5-5-6_Rev120402.XLSfig5-6fish

**Figure 5-7**
**Smallmouth Bass Whole Body**
**Total PCB Concentrations**

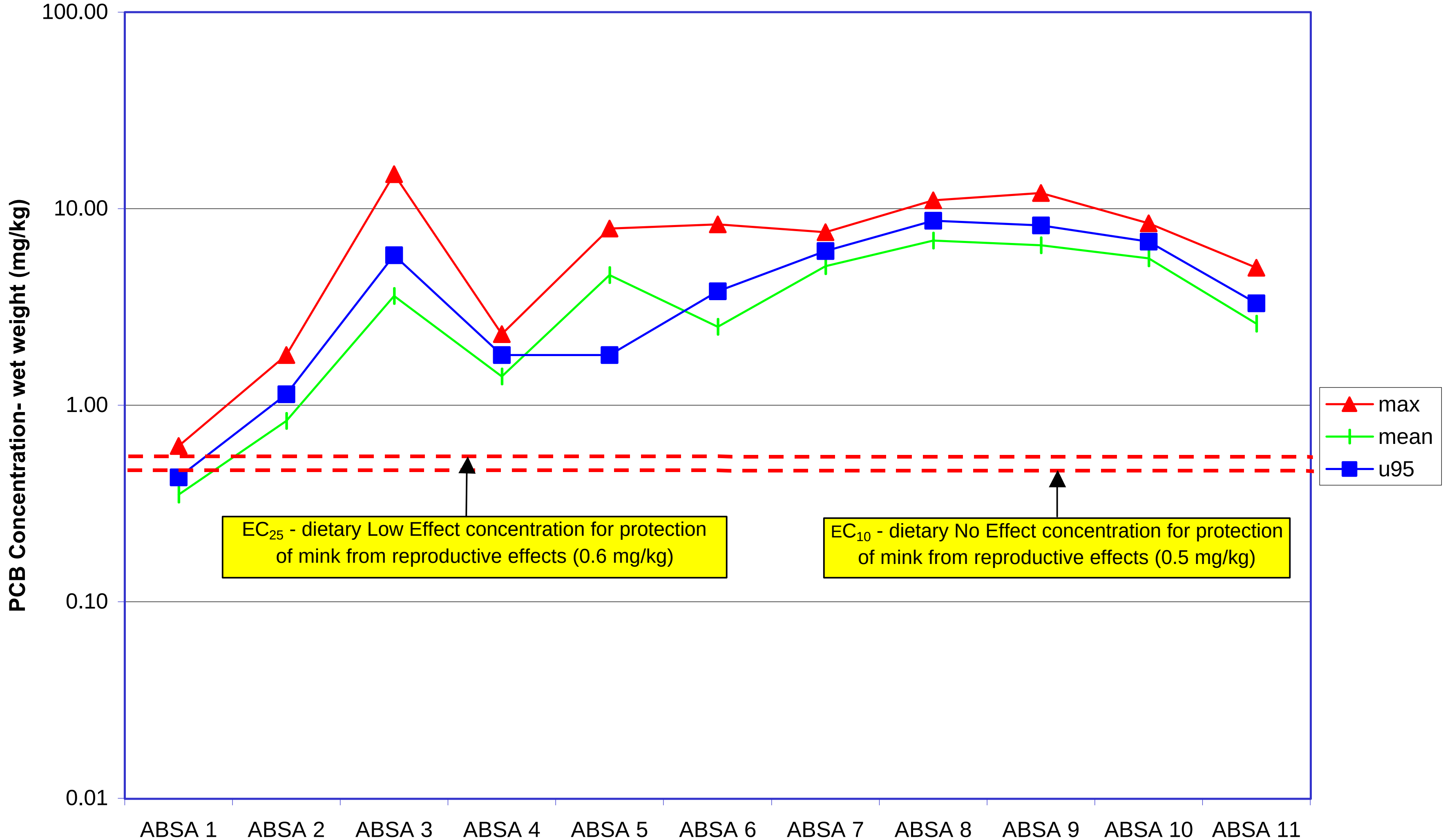



FIG5-7-9_Rev042303.xlsfig5-7

# Figure 5-8
## Common Carp Whole Body
## Total PCB Concentrations

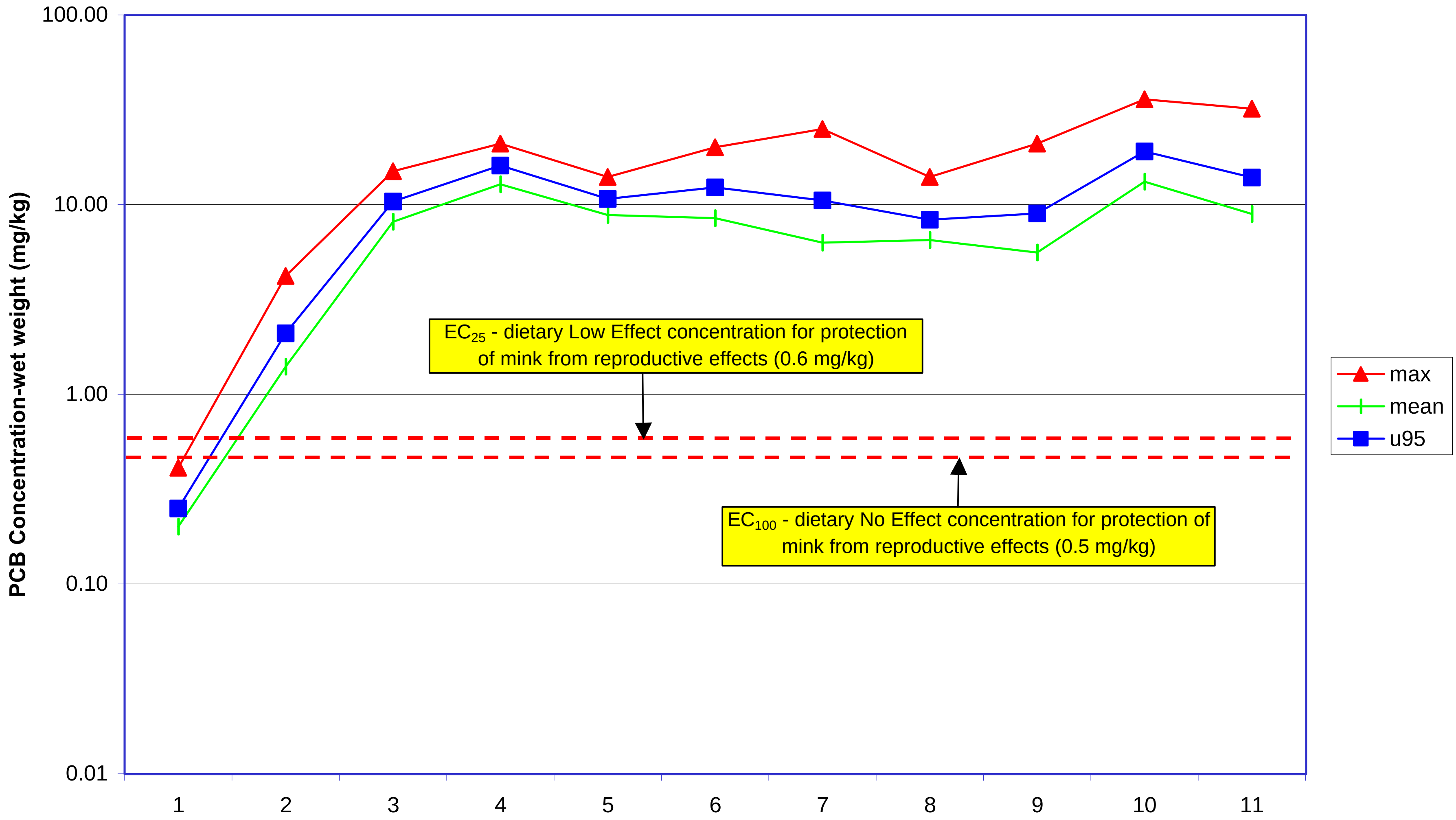



FIG5-7-9_Rev042303.xlsFig5-8

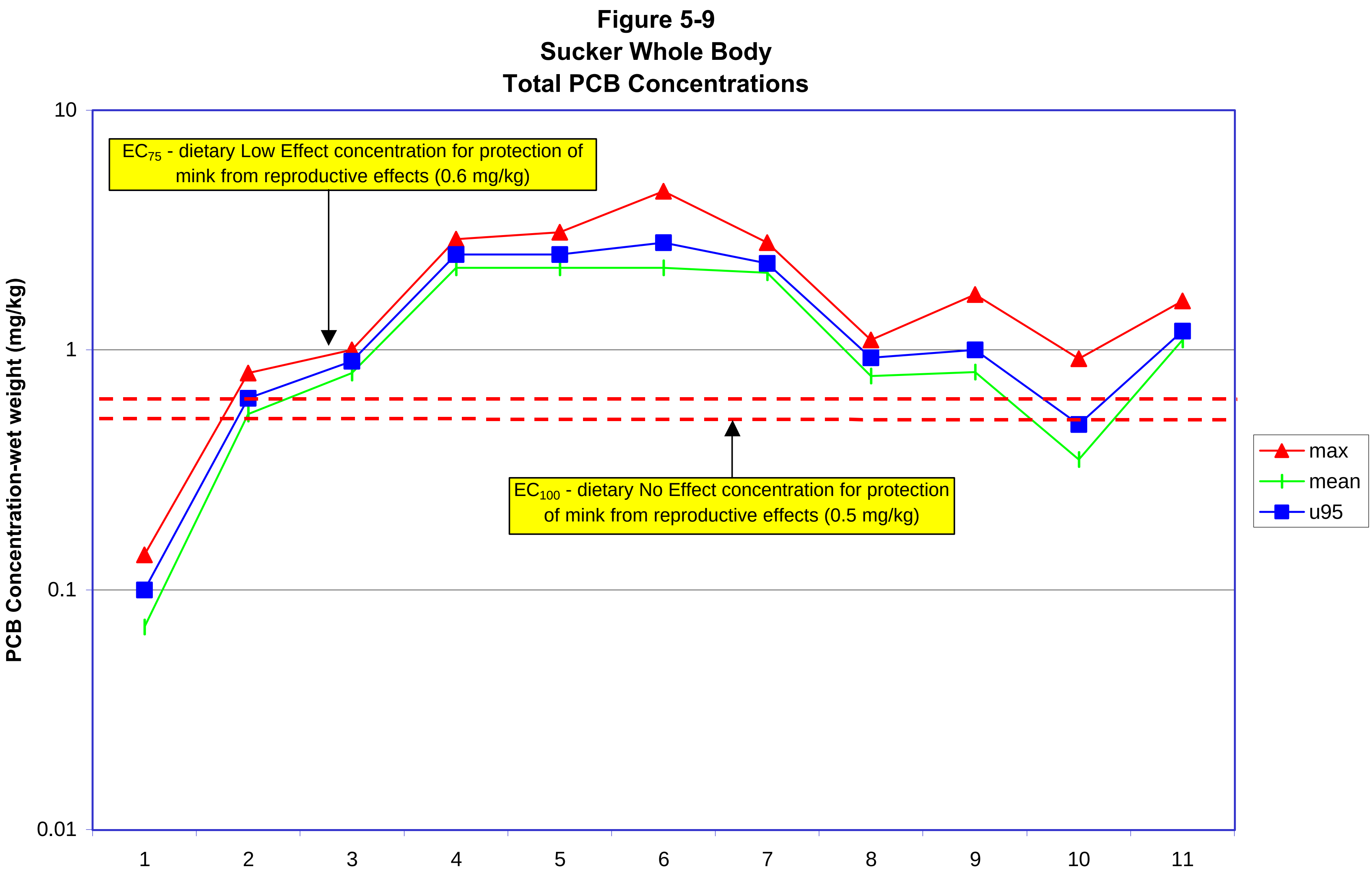



FIG5-7-9_Rev042303.xlsFig5-9

**Figure 5-10**
**Total PCB Concentrations**
**Muskrat Carcass**

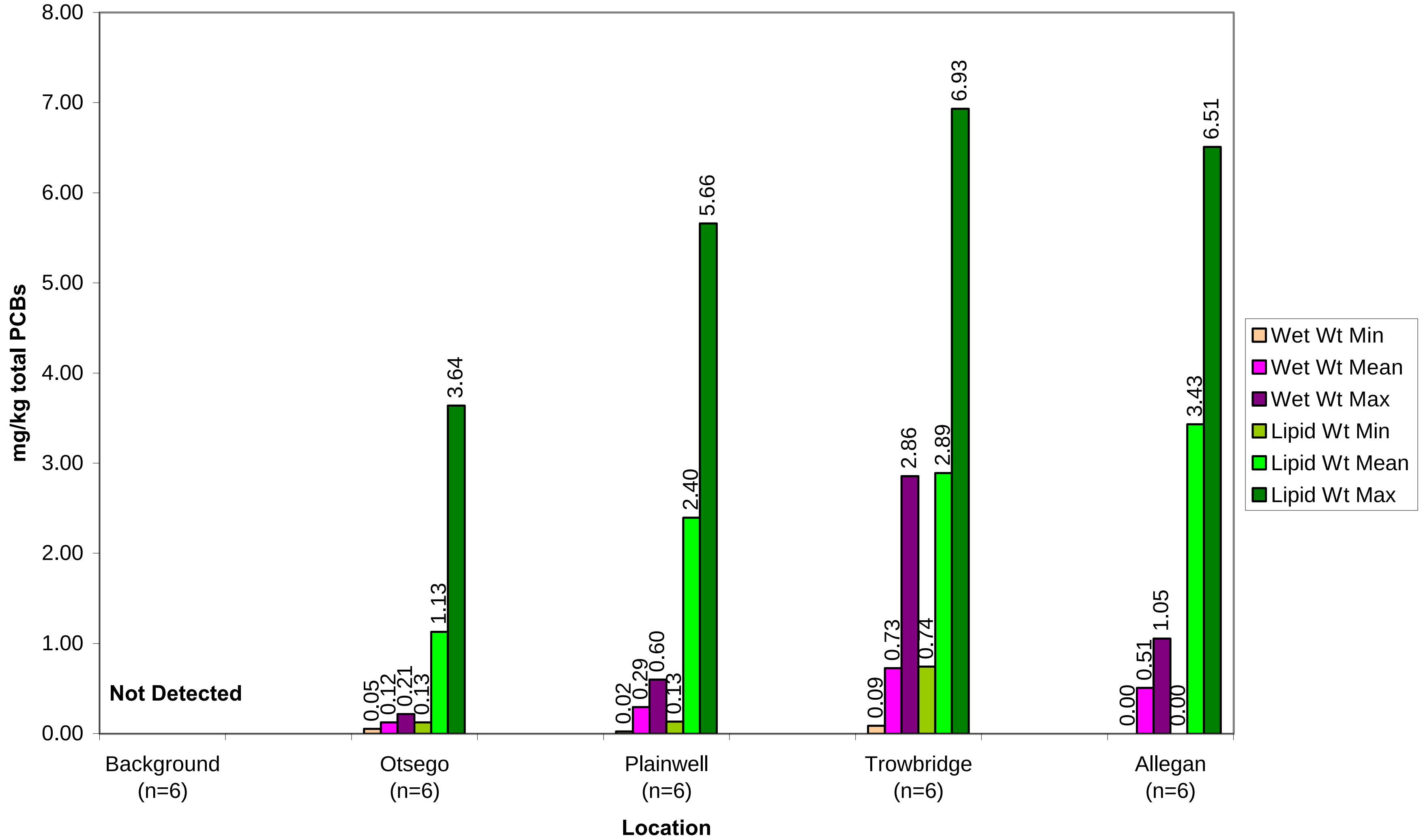


**Figure 5-11**
**Total PCB Concentrations**
**Muskrat Liver**

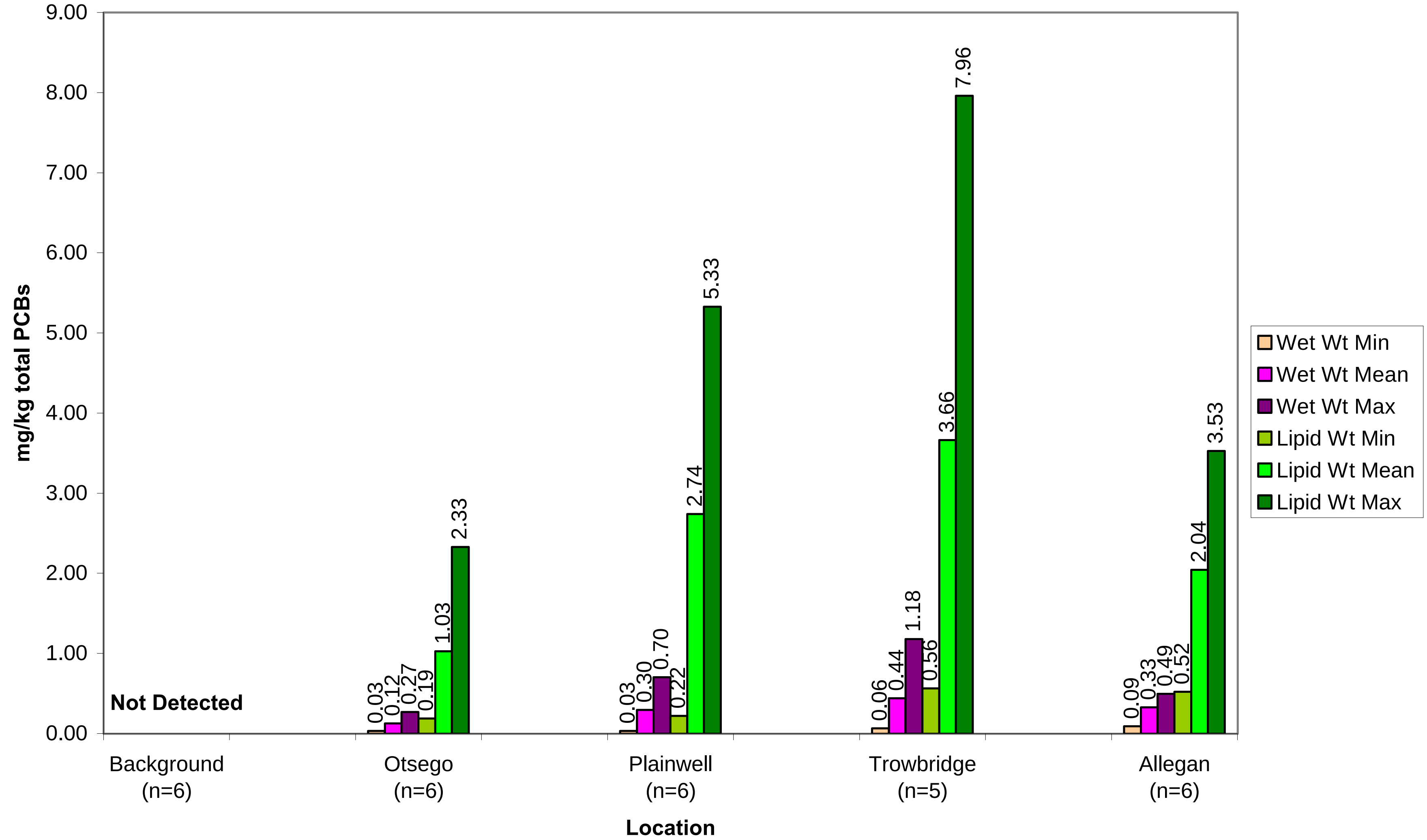
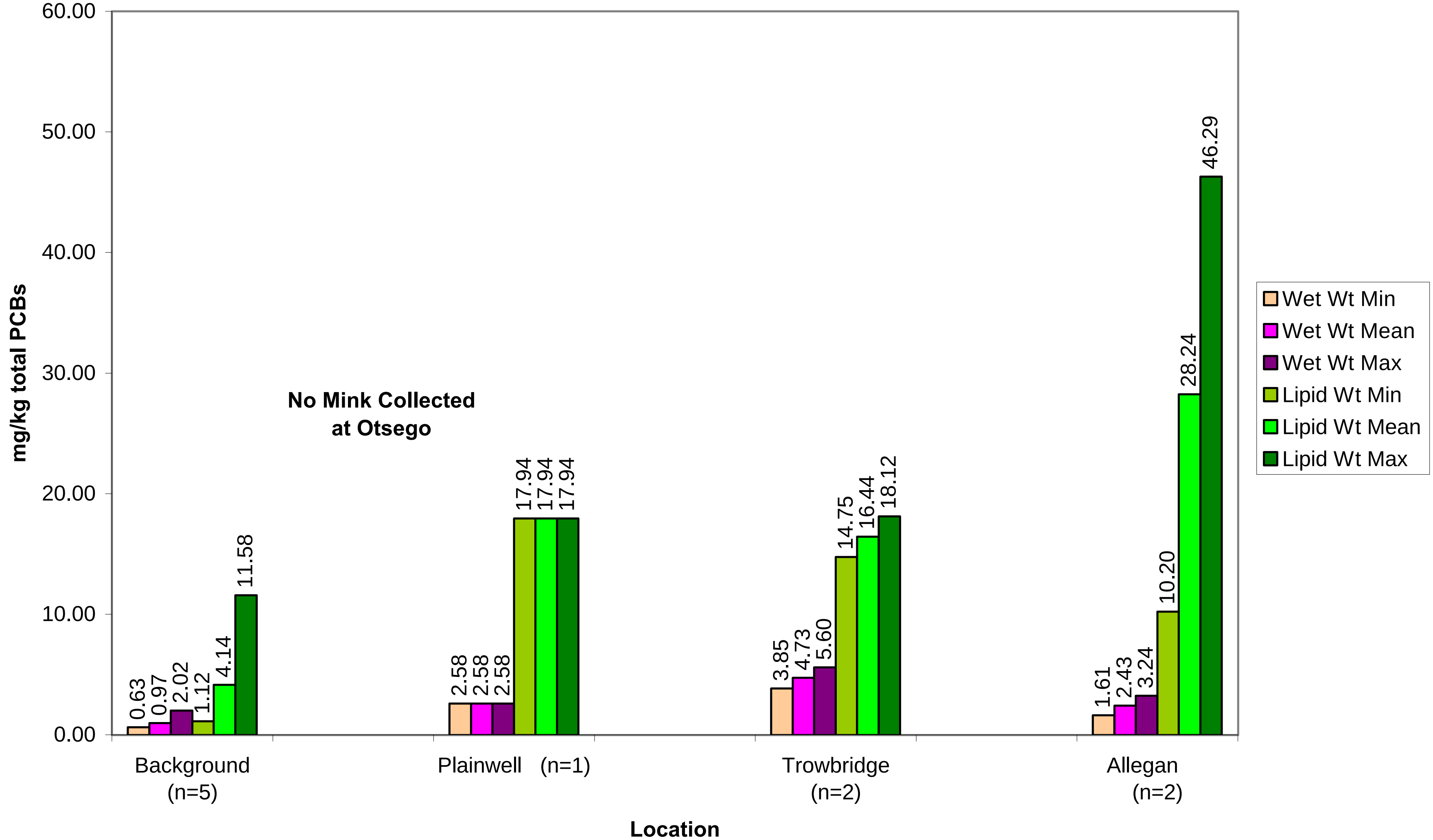


**Figure 5-12**
**Total PCB Concentrations**
**Mink Carcass**



# Figure 5-13
# Total PCB Concentrations
# Mink Liver

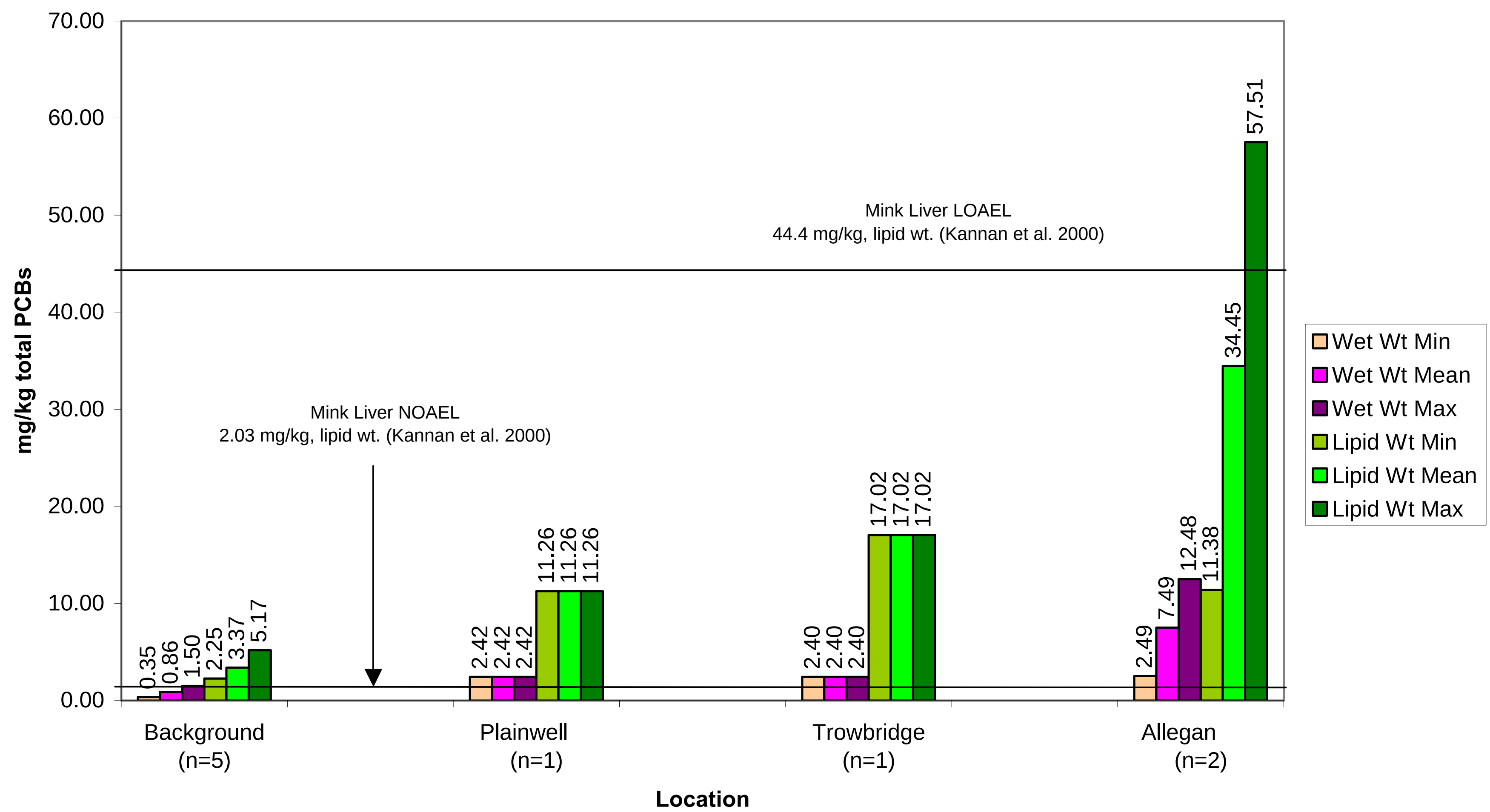


**Table 5-1**
**Summary of the PCB Food Web Model, Terrestrial/Wetland Species**
**API/PC/KR**

| Receptor | Estimated Average Potential Daily Dose (mg/kg/d) | Low Effect Concentration LOAEL or $ED_{25}$ (mg/kg/d) (target species) | No Effect Concentration NOAEL or $ED_{10}$ (mg/kg/d) (target species) | Reference |
|---|---|---|---|---|
| American Robin | 0.9044[1] | 0.5 (chicken) | 0.4 (chicken) | See Appendix C-1, C-2 |
| Mink | 1.6988[2] | 0.11 (mink) | 0.091 (mink) | See Appendix C-1, C-2 |
| White-footed/ Deer Mouse | 0.3109 | 1.35 (mouse) | 0.45 (estimated from mouse LOAEL/3) | See Appendix C-1, C-2 |
| Bald Eagle | 2.1606 | 0.5 (chicken) | 0.4 (chicken) | See Appendix C-1, C-2 |
| Muskrat | 0.4167 | 5 (rat) | 1.7 (estimated from rat LOAEL/3) | See Appendix C-1, C-2 |
| Red Fox | 2.4764 | 5 (dog) | 1 (dog) | See Appendix C-1, C-2 |
| Great Horned Owl | 2.0551 | 1.2 (estimated from NOAEL*3) | 0.41 (screech owl) | See Appendix C-1, C-2 |

[1] Terrestrial plant component of diet based on soil-to-fruit BAF (tomato, CDM 2000)
[2] Diet from Alexander 1977 (river, year-round) in EPA 1993
- unadjusted values = 85% fish
- adjusted values:
  - birds/mammals = 6%, adjusted for birds = 5%, mammals = 10% (5% mouse, 5% muskrat)
  - vegetation = 1%, adjusted to 0%
  - unidentified = 1%, adjusted to 0%
  - crustaceans = 4%, adjusted to 0%
  - amphibians = 3%, adjusted to 0%
- adjustments made to include only prey items for which site-specific PCB data are available

**Table 5-2**
**PRGs for PCBs in FP Sediment/Surface Soil for Representative Terrestrial Food Web Species**
**API/PC/KR**

| Receptor | Low Effect DOSE (mg PCB/kg-d) | No Effect DOSE (mg PCB/kg-d) | Daily Dose (mg/kg-d) | FPSED/SS Total PCB Concentration[1] (mg/kg) | PRG RANGE (No Effect to Low Effect[2]) (mg PCB/kg FPSED) |
|---|---|---|---|---|---|
| Robin | 0.5 | 0.4 | 0.9044 | 14.6 | 6.5 –8.1 |
| Great Horned Owl | 1.2 | 0.41 | 2.0551 | | 2.9 – 8.5 |
| Red Fox | 5 | 1 | 2.4764 | | 5.9 – 29.5 |
| White-footed/ Deer Mouse | 1.35 | 0.45 | 0.3109 | | 21.1 – 63.4 |

[1] FP SED/SS total PCB concentration based on mean of U95 PCB concentration for ABSAs 5, 7, and 8 (Plainwell, Otsego, and Trowbridge areas)
[2] NOAEL to LOAEL or $ED_{10}$ to $ED_{25}$, see Appendix C-2-A for detailed calculations and text for discussion

**Table 5-3**
**Summary of Total PCB Risks to Ecological Receptors**
**API/PC/KR**

| Ecological Receptor Group or Target Species | Exposure Concentration (dose or exposure media) | No Effect Dose | No Effect Dose-Based HQ | Low Effect Dose | Low Effect Dose-Based HQ |
|---|---|---|---|---|---|
| Mink | 1.6988 mg/kg/d | 0.091 mg/kg/d | **19** | 0.11 mg/kg/d | **15** |
| Bald Eagle | 2.1606 mg/kg/d | 0.4 mg/kg/d | **5.4** | 0.5 mg/kg/d | **4.3** |
| Great Horned Owl | 2.0551 mg/kg/d | 0.41 mg/kg/d | **5.0** | 1.2 mg/kg/d | **1.7** |
| American Robin | 0.9044 mg/kg/d | 0.4 mg/kg/d | **2.3** | 0.5 mg/kg/d | **1.8** |
| Red Fox | 2.4764 mg/kg/d | 1.0 mg/kg/d | **2.5** | 5.0 mg/kg/d | 0.5 |
| White-footed/Deer Mouse | 0.3109 mg/kg/d | 0.45 mg/kg/d | 0.7 | 1.35 mg/kg/d | 0.2 |
| Muskrat | 0.4167 mg/kg/d | 1.7 mg/kg/d | 0.3 | 5.0 mg/kg/d | 0.08 |
| | **(mean U95 SW conc)** | **Chronic AWQC[1]** | **AWQC-based Hazard Quotient** | | |
| Generic Piscivorous Wildlife | 0.043 µg/L surface water | 0.014 µg/L surface water | 3.1 | | |
| | | **NOAEC[2]** | **NOAEC-based HQ** | **LOAEC[3]** | **LOAEC-based HQ** |
| Carp | 0.043 µg/L surface water | 0.02 µg/L surface water | **2.2** | 0.2 µg/L | 0.22 |
| Sucker | 0.043 µg/L surface water | 0.02 µg/L surface water | **2.2** | 0.2 µg/L | 0.22 |
| Smallmouth Bass | 0.043 µg/L surface water | 0.04 µg/L surface water | **1.1** | 0.4 µg/L | 0.11 |
| Aquatic Invertebrates | 0.043 µg/L surface water | 0.08 µg/L surface water | 0.54 | 0.8 µg/L | 0.05 |
| Salmonid Fish | 0.043 µg/L surface water | 0.1 µg/L surface water | 0.43 | 1.0 µg/L | 0.04 |

[1] Chronic AWQC (Final Residue Value) for PCBs is based on protection of piscivorous wildlife. Data specifically from studies of mink and ingestion of salmonid fish. In most cases, chronic AWQC are intended to protect 95 percent of the aquatic species. EPA modifies this approach for certain chemicals that readily bioaccumulate and move easily through food chains to upper trophic level predators. In these cases, AWQC are further lowered to protect sensitive wildlife that may consume contaminated prey. For PCBs, the chronic AWQC (0.014 ug/L) is specifically based on (1) the lowest maximum permissible tissue concentration for dietary items consumed by mink and (2) the geometric mean whole body BCF values for salmonid species. The derivation of the chronic AWQC follows:

$$\text{Freshwater chronic AWQC} = \frac{\text{maximum permissible tissue concentration}}{\text{geometric mean BCF for salmonid fish}}$$

$$0.014\text{ug/L} = \frac{0.64\text{ mg/kg}}{45{,}000}$$

All values used in the derivation of the national chronic AWQC are presented in EPA 1980. Because the national chronic AWQC for PCBs is based on wildlife protection, it is more accurately referred to as the Freshwater Final Residue Value.

[2] Estimated from LOAEC/10

[3] From Appendix C-1, except for salmonid value (brook trout chronic value, Mauck, et al. 1978 in EPA 1980)

**Table 5-4.a**
**Hazard Quotients for Birds Eggs – Egg TRVs from Table 4-9**

| Bird Species | Mean Egg PCB Conc (n) | Egg NOAEC[1] | Egg LOAEC[1] | NOAEC HQ | LOAEC HQ |
|---|---|---|---|---|---|
| Bald eagle | 77.6 (4) | 1.5 (bald eagle) | 7.7 (bald eagle) | **52** | **10** |
| Great horned owl | 43.1 (3) | 1.3 (bald eagle) | 6.4 (bald eagle) | **33** | **6.7** |
| Red tailed hawk | 11.3 (3) | 1.3 (bald eagle) | 6.4 (bald eagle) | **8.7** | **1.8** |
| Great blue heron | 10.5 (6) | 5.8 (Foster's tern) | 20.6 (Foster's tern) | **1.8** | 0.5 |
| Wood thrush | 1.93 (1) | 1.1[2] (tree swallow) | 5.7 (tree swallow) | **1.8** | 0.3 |
| Yellow warbler | 1.31 (1) | 1.1[2] (tree swallow) | 5.7 (tree swallow) | **1.2** | 0.2 |
| Red winged blackbird | 1.2 (5) | 1.1[2] (tree swallow) | 5.7 (tree swallow) | **1.1** | 0.2 |
| American robin | 2.1 (2) | 2.8 (chicken) | 6.2 (chicken) | 0.8 | 0.3 |
| Wood duck | 0.43 (6) | 2.8 (chicken)[3] | 6.2 (chicken)[3] | 0.2 | 0.07 |

All data in mg/kg total PCBs
1 Mean NOAEC or LOAEC for most closely related species or species with similar diet (Table 4-9)
2 Estimated from LOAEC/5, based on similar data for other species
3 NOAEC and LOAEC based on mean value for egg hatchability

**Table 5-4.b**
**Hazard Quotients for Birds Eggs – Egg TRV from Appendix D (chicken studies)**

| Bird Species | Mean Egg PCB Conc (n) | Egg NOAEC[1] | Egg LOAEC[1] | NOAEC HQ | LOAEC HQ |
|---|---|---|---|---|---|
| Bald eagle | 77.6 (4) | 1.0 | 1.5 | **78** | **52** |
| Great horned owl | 43.1 (3) | 1.0 | 1.5 | **43** | **29** |
| Red tailed hawk | 11.3 (3) | 1.0 | 1.5 | **11** | **7.3** |
| Great blue heron | 10.5 (6) | 1.0 | 1.5 | **11** | **7.0** |
| American robin | 2.1 (2) | 1.0 | 1.5 | **2.1** | **1.4** |
| Wood thrush | 1.93 (1) | 1.0 | 1.5 | **1.9** | **1.3** |
| Yellow warbler | 1.31 (1) | 1.0 | 1.5 | **1.3** | 0.9 |
| Red winged blackbird | 1.2 (5) | 1.0 | 1.5 | **1.2** | 0.8 |
| Wood duck | 0.43 (6) | 1.0 | 1.5 | 0.4 | 0.3 |

All data in mg/kg total PCBs
1 NOAEC or LOAEC from Appendix D

**Table 5-5**
**Media-Specific and Species-Specific Levels of Protection**
**API/PC/KR**

| Media | Total PCB Concentration | Receptor | Description | Equation |
|---|---|---|---|---|
| **Surface Water** | 0.00012 µg/L | Avian and Mammalian Wildlife | MDEQ Surface Water Quality Division value for protection of avian and mammalian wildlife. | NA |
| | 0.0016 µg/L | Mink | No Effect value for fish tissue threshold (0.5 mg/kg) to protect mink. Mean fish BAF = 305,000. | 0.5 mg/kg / 305,000 * 1,000 |
| | 0.00197 µg/L | Mink | Low Effect value for fish tissue threshold (0.6 mg/kg) to protect mink (mean fish BAF = 305,000) . | 0.6 mg/kg / 305,000 * 1,000 |
| **Instream Sediment**<br><br>**Floodplain Sediment/ Soil**[1] | 0.036 mg/kg | Avian and Mammalian Wildlife | Calculated from MDEQ Surface Water Quality Division SW value for protection of avian and mammalian wildlife (0.00012 µg/L) and mean site-specific $K_d$ (302,000). | 0.00012 µg/L * 302,000 / 1,000 |
| | 0.1 mg/kg | Avian and Mammalian Wildlife | NOAEC-base value based on MDEQ-SWQD default variables (from GLI) for water value protective of mink (0.000132 ug/L), NOAEC for mink (0.5 mg/kg, BAF for trophic level 3 fish (1,139,000), fish lipid (6.46%), and site-specific values for sediment Foc (0.082) and carp BSAF (1.9). | [(0.000132 ug/L)(1,139,000 L/kg) / 6.46%] (8.2%) / 1.9 |
| | 0.5 - 0.6 mg/kg | Mink | No Effect ($EC_{10}$) and Low Effect ($EC_{25}$) values to allow pore water PCB concentration to remain below SW thresholds of 0.0016 and 0.00197 µg/L, respectively. Mean site-specific SED/SW partition factor ($K_d$) = 302,000. No and Low Effect fish tissue thresholds = 0.5 and 0.6 mg/kg, mean site-specific Biota/SED partition factor = 1.02. | No Effect = 0.0016 µg/L * 302,000 / 1,000 or 0.5 mg/kg * 1.02<br><br>Low Effect = 0.00197 µg/L * 302,000 / 1,000 or 0.6 mg/kg * 1.02 |
| | 1.4 - 1.7 mg/kg | Bald Eagle | No Effect ($ED_{10}$) and Low Effect ($ED_{25}$) values resulting from food chain modeling, assuming fish-based diet (77%), dietary No Effect Dose = 0.4 mg/kg-d, dietary Low Effect Dose = 0.5 mg/kg-d, average daily dose = 2.1606 mg/kg-d, and U95 PCB Conc SED = 7.3 mg/kg. | No Effect = 0.4 mg/kg-d / 2.1606 mg/kg-d * 7.3 mg/kg<br><br>Low Effect = 0.5 mg/kg-d / 2.1606 mg/kg-d * 7.3 mg/kg |

| | | | | |
|---|---|---|---|---|
| **Surface Soil**<br><br>**Floodplain Sediment/ Soil**[2] | 6.5 – 8.1 mg/kg | Robin | No Effect ($ED_{10}$) and Low Effect ($ED_{25}$) values to protect omnivorous songbirds, represented by American robin. Dietary No Effect Dose = 0.4 mg/kg-d, dietary Low Effect Dose = 0.5 mg/kg-d, average daily dose = 0.9044 mg/kg-d, mean site-wide U95 PCB Conc FP SED = 14.6 mg/kg. | No Effect = 0.4 mg/kg-d / 0.9044 mg/kg-d * 14.6 mg/kg<br><br>Low Effect = 0.5 mg/kg-d / 0.9044 mg/kg-d * 14.6 mg/kg |
| | 2.9 - 8.5 mg/kg | Great Horned Owl (GHO) | NOAEL- and LOAEL-based value to protect non-piscivorous raptors, represented by GHO. Dietary NOAEL = 0.41 mg/kg-d, LOAEL = 1.2 mg/kg-d, average daily dose = 2.0551 mg/kg-d, mean site-wide U95 PCB Conc FP SED = 14.6 mg/kg | NOAEL = 0.41 mg/kg-d / 2.0551 mg/kg-d * 14.6 mg/kg<br><br>LOAEL = 1.2 mg/kg-d / 2.0551 mg/kg-d * 14.6 mg/kg |
| | 5.9 - 29.5 mg/kg | Red Fox | NOAEL- and LOAEL-based value to protect top mammalian predators, represented by red fox. Dietary NOAEL = 1 mg/kg-d, LOAEL = 5 mg/kg-d, average daily dose = 2.4764 mg/kg-d, mean site-wide U95 PCB Conc FP SED = 14.6 mg/kg | NOAEL = 1 mg/kg-d / 2.4764 mg/kg-d * 14.6 mg/kg<br><br>LOAEL = 5 mg/kg-d / 2.4764 mg/kg-d * 14.6 mg/kg |
| | 21 - 63 mg/kg | White-footed/ Deer Mouse | NOAEL- and LOAEL-based value to protect omnivorous rodents, represented by white-footed/deer mouse. Dietary NOAEL = 0.45 mg/kg-d, LOAEL = 1.35 mg/kg-d, average daily dose = 0.31094 mg/kg-d, mean site-wide U95 PCB Conc FP SED = 14.6 mg/kg | NOAEL = 0.45 mg/kg-d / 0.31094 mg/kg-d * 14.6 mg/kg<br><br>LOAEL = 1.35 mg/kg-d / 0.31094 mg/kg-d * 14.6 mg/kg |

1 Assumes aquatic environment, exposures to instream sediment , site-wide (ABSAs 3-9) U95 total PCB concentration = 7.3 mg/kg
2 Assumes terrestrial environment, exposure to floodplain sediments/soils, site-wide (ABSAs 3-9) U95 total PCB concentration = 14.6 mg/kg